COMPARISON OF MEASUREMENTS OF EUROPEAN RADIOSONDE STATIONS IN THE 100 HPA LEVEL

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Contents:

1. Preliminary Remarks

The objective of the following study is to determine standards for the quality of radiosonde measurements in Central Europe on the basis of figures.

As criteria for the study three systematic errors and three scatter errors have been used.

- Systematic errors are average values of the differences between the radiosonde measurement and the First Guess of the numerical analysis of the European Centre for Medium Range Weather Forecasts (ECMWF), Reading, at 00 UTC and 12 UTC and the day/night difference of the average values.
- Scatter errors are standard deviations at 00 UTC and 12 UTC and the day/night difference of the standard deviations.

The values of the 100 hPa level only have been considered. A plausible extension to other levels would have gone far beyond the temporal limits of the study.

The figures for the study have been recalled from the data material of the ECMWF by section S2 of the Central Office of the Deutscher Wetterdienst. The data of 23 selected radiosonde stations have been used.

2. Tables

2.1 Systematic Errors

The average value of the difference between the value measured by the station and the First Guess of the numerical analysis of the ECMWF is defined as systematic error of the station. In this context it has to be mentioned that the height of the analysed level depends on the measured values of neighbouring radiosondes. That means, the systematic error of a determined radiosonde will change when the measured values of one or several radiosondes in the vicinity will systematically be changed, e.g. by amending the radiation error correction values or by introducing a new sonde model.

The quantity of the defined systematic error of a radiosonde does not say anything about the actual deviation of the sonde from the true value. Only the systematic deviation from a fictive average value, the analysis level, is determined.

A negative systematic error means that the corresponding sonde is yielding lower temperature values compared with other sondes. Therefore its geopotential values are lower than the analysed level.

There are reasons for the assumption that in the following study a correctly measuring ideal sonde would have a "systematic" error with a negative sign.

2.1.1 Bias, 00 UTC

The table on the following page shows the monthly averages of the difference between station and analysis of night ascents.

As homogenity is concerned a negative systematic error is as unwelcome as a positive one. Therefore in table 1 the so-called RMS error (Root-Mean-Square), i.e. the square average, is used to evaluate the station. In this case the arithmetical average cannot be used, as negative and positive errors of a station would be cancelled out mutually.

In table 1 the smallest, respectively largest RMS value is 8.4 gpm, respectively 55.9 gpm. The relation between the figures is 1 : 7. This is a very wide range.

The figures of the geopotential error in table 1 can be interpreted by means of the following data.

- A temperature error of	1.0	K
results in a geopotential error of	67.4	gpm
	and/or	
- A geopotential error of	10	gpm
requires a temperature error of	0.15	K

The temperature error is defined as average value between surface and 100 hPa and the indicated geopotential error refers to the 100 hPa level. With an average value of the pressure error of 1 hPa another error of 5 gpm would be resulting in the geopotential of the 100 hPa Level. Errors in the humidity measurement have a negligible effect on the geopotential.

In table 1 there is a bias of approximately 90 gpm between the station with the absolutely highest negative monthly value and the one with the largest positive value in March. This means that the temperature measurements of the corresponding stations differed in the entire layer ground/100 hPa by ca. 1.3 K in the monthly average.

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Station		1987						
Name	No	JAN	FEB	MAR	APR	MAY	JUN	RMS value
Greifswald	09 184	-0,9	11,1	2,3	7,8	14,3	5,0	8,36
Lindenberg	09 393	-10,7	-9,0	-12,4	-4,5	-9,6	-2,9	8,85
München	10 868	-9,1	-2,7	-7,7	-8,9	-12,9	-14,1	9,95
Prag	11 520	-3,5	-10,8	-24,0	0,4	-3,9	0,0	10,96
Gibraltar	08 495	-9,7	15,3	-10,2	-13,4	-7,7	14,3	12,08
De Bilt	06 260	20,0	23,2	2,9	18,4	12,3	9,6	15,96
Essen	10 410	-18,4	-17,7	-27,8	-19,2	-19,2	-7,6	19,23
Belgrad	13 275	-19,3	0,0	-33,6	--	--	-19,5	21,69
Rom	16 245	31,6	--	--	16,9	16,5	20,2	22,16
Schleswig	10 035	-28,4	-23,1	-30,3	-15,7	-22,2	-10,2	22,74
Udine	16 044	27,6	29,2	20,3	19,9	24,1	26,0	24,76
Stuttgart	10 739	-24,3	-22,1	-33,8	-32,1	-15,9	-21,1	25,66
Mailand	16 080	36,9	31,7	14,8	20,2	21,3	25,1	26,07
Hannover	10 338	-25,0	-25,6	-33,5	-36,2	-22,5	-13,5	27,08
Madrid	08 221	26,8	33,3	23,7	27,8	30,9	26,3	28,31
Payerne	06 610	-41,4	-35,6	-37,3	-36,7	-42,5	-34,1	38,05
Crawley	03 774	-35,3	-33,1	-46,3	-41,1	-33,7	-37,9	38,18
Brest	07 110	-5,7	-29,8	-51,3	-52,3	-28,1	-43,5	38,66
Trappes	07 145	-42,8	-37,2	-54,8	-36,7	-23,6	-41,1	40,44
Wien	11 035	-42,8	-43,7	-55,2	-47,2	-27,4	-27,8	41,92
Camborne	03 808	-40,4	-40,3	-55,5	-39,9	-38,7	-37,2	42,45
Lyon	07 481	-25,5	-45,8	-61,3	-40,7	-40,5	-39,7	43,55
Uccle	06 447	-62,3	-57,2	-66,2	-47,6	-52,2	-47,2	55,91

Tab. 1 Bias, gpm

100 hPa level, 00 UTC

2.1.2 Bias, 12 UTC

Table 2 on the following page shows the values of day ascents. The smallest, respectively largest RMS value at 12 UTC is 4.5 gpm, respectively 37.6 gpm. The relation between the two extreme RMS values is 1 : 8.

It is remarkable that nearly at all stations the biases at 12 UTC are smaller than at 00 UTC. It can be presumed that this fact has to be attributed to the characteristics of the analysis model. Due to the considerably varying radiation errors of the participating radiosondes it could have been assumed that the larger errors would occur at 12 UTC.

AFE München

Station		1987						
Name	No	JAN	FEB	MAR	APR	MAY	JUN	RMS value
Lindenberg	09 393	5,6	4,0	1,3	1,4	6,3	-5,4	4,47
Trappes	07 145	-10,1	-1,8	-13,6	-1,0	-4,0	-1,5	7,18
München	10 868	-4,0	0,5	-9,7	-4,6	-8,6	-11,2	7,43
Essen	10 410	-8,3	-15,0	-9,1	-12,7	-6,9	-0,1	9,88
Wien	11 035	6,2	-2,4	-3,2	8,1	17,7	16,9	10,95
Gibraltar	08 495	3,0	-3,5	-20,3	-10,3	-8,9	-10,7	11,05
Brest	07 110	15,6	-6,4	-15,7	3,5	9,9	10,1	11,13
Lyon	07 481	-25,5	-5,0	-12,0	-3,7	-1,5	-5,0	11,97
Prag	11 520	-17,1	-0,9	-3,7	4,1	12,2	21,5	12,48
De Bilt	06 260	18,4	14,9	1,0	3,0	-21,6	-16,0	14,68
Schleswig	10 035	-17,5	-0,4	-19,3	-18,1	-17,2	-4,7	14,86
Greifswald	09 184	16,0	20,7	16,3	9,7	15.5	8,3	15,02
Udine	16 044	28,8	26,1	11,2	-7,3	-6,5	-18,8	18,64
Payerne	06 610	-27,3	-11,7	-10,1	-24,8	-25,5	-11,7	19,94
Mailand	16 080	34,8	31,0	5,2	-8,0	-8,7	-15,5	20,73
Stuttgart	10 739	-18,2	-33,6	-32,0	-24,6	-19,7	-9,3	24,37
Rom	16 245	22,4	--	--	-22,3	-26,1	-29,5	25,25
Madrid	08 221	33,5	34,9	33,1	20,5	5,3	-1,2	25,45
Hannover	10 338	-16,2	-19,3	-28,6	-40,5	-25,3	-18,4	26,06
Uccle	06 447	-19,7	-16,0	-16,0	-38,1	-52,7	-26,4	31,16
Crawley	03 774	-27,2	-27,4	-36,1	-40,3	-36,1	-29,8	33,19
Belgrad	13 275	19,1	52,1	24,7	--	--	--	35,07
Camborne	03 808	-30,4	-36,2	-50,6	-35,2	-38,9	-30,4	37,58

Tab. 2

Bias, gpm

100 hPa level, 12 UTC

2.1.3 Day/Night Difference (DND) of Bias

The figures of the DND are shown in table 3. They have been calculated on the basis of the values of the tables 1 and 2. The following relations apply to the systematic error SE, the average value of the measurement M and the one of the analysis A at the hour of observation X or 12 UTC or OO UTC

$$SE(x) = M(x) - A(x)$$

$$DND = SE(12) - SE(OO)$$

$$DND = [M(12) - M(OO)] - [A(12) - A(OO)]$$

It is assumed that in the third equation the value of the second square bracket may be neglected. If this is the case DND will become independent from the value of the analysis A and of the features of the numerical model. Consequently DND provides very suitable figures.

The third equation shows that a negative value of DND is resulting when the values of the geopotential at 12 UTC are on the average smaller, i.e. lower, than at OO UTC. This occurs when a too large radiation error correction is made in the temperature measurement. On the other hand larger positive DND values might result if the radiation error correction is too small, and the values measured at 12 UTC are higher than the ones at OO UTC.

The smallest and the largest value of DND is shown in table 3 as 3.8 gpm and 50.3 gpm. The characteristic figures are in a relation of ca. 1 : 13.

Station		1987						RMS
Name	No	JAN	FEB	MAR	APR	MAY	JUN	value
München	10 868	5,1	3,2	-2,0	4,3	4,3	2,9	3,78
Hannover	10 338	8,8	6,3	4,9	-4,3	-2,8	-4,9	5,65
Camborne	03 808	10,0	4,1	4,9	4,7	-0,2	6,8	5,90
Crawley	03 774	8,1	5,7	10,2	0,8	-2,4	8,1	6,76
Stuttgart	10 739	6,1	-11,5	1,8	7,5	-3,8	11,8	7,99
Greifswald	09 184	16,9	9,6	14,0	1,9	1,2	3,3	9,91
Essen	10 410	10,1	2,7	18,7	6,5	12,3	7,5	10,87
Schleswig	10 035	10,9	22,7	11,0	-2,4	5,0	5,5	11,66
Lindenberg	09 393	16,3	13,0	13,7	5,9	15,9	-2,5	12,36
Gibraltar	08 495	12,7	-18,8	-10,1	3,1	-1,2	-25,0	14,45
Prag	11 520	-13,6	9,9	20,3	3,7	16,1	21,5	15,44
Madrid	08 221	6,7	1,6	9,4	-7,3	-25,6	-27,5	16,33
De Bilt	06 260	-1,6	-8,3	-1,9	-15,4	-33,9	-25,6	18,78
Payerne	06 610	14,1	23,9	27,2	11,9	17,0	22,4	20,18
Mailand	16 080	-2,1	-0,7	-9,6	-28,2	-30,0	-40,6	23,95
Udine	16 044	1,2	-3,1	-9,1	-27,2	-30,6	-44,8	25,09
Uccle	06 447	42,6	41,2	50,2	9,5	-0,5	20,8	33,05
Trappes	07 145	32,7	35,4	41,2	35,7	19,6	39,6	34,75
Lyon	07 481	0,0	40,8	49,3	37,0	39,0	34,7	36,94
Rom	16 245	-9,2	--	--	-39,2	-42,6	-49,7	38,43
Brest	07 110	21,3	23,4	35,6	55,8	38,0	53,6	40,21
Wien	11 035	49,0	41,3	52,0	55,3	45,1	44,7	48,13
Belgrad	13 275	38,4	52,1	58,3	--	--	--	50,29

Tab. 3 Day/Night Difference (12 UTC minus 00 UTC)
of Bias, gpm
100 hPa level

2.2 Scatter Errors

The standard deviation of the differences between the radiosonde measurement and the First Guess of the numerical analysis is defined as scatter error of the station. The value shows how reproducible the measurements are.

A low scatter is necessary, however not sufficient to achieve great accuracy.

A good radiosonde should have not only a small scatter error but also a small systematic error.

2.2.1 Standard Deviation, OO UTC

On the next page, in table 4 the figures of the standard deviations of night ascents have been compiled. The smallest and largest RMS values are 14.9 gpm and 34.8 gpm.

Scatter of radiosonde measurements may vary in the relation of ca. 1 : 2.

AFE München

Station		1987						
Name	No	JAN	FEB	MAR	APR	MAY	JUN	RMS value
Crawley	03 774	14,1	13,9	16,3	14,6	11,5	17,9	14,85
München	10 868	21,0	15,6	13,5	15,1	13,4	8,2	14,95
De Bilt	06 260	16,9	15,7	13,6	13,6	11,0	17,9	14,96
Camborne	03 808	16,7	16,6	16,1	16,8	11,9	12,4	15,23
Rom	16 245	16,4	--	--	14,4	18,1	11,6	15,32
Udine	16 044	13,2	20,5	11,4	20,7	8,0	13,9	15,33
Mailand	16 080	18,1	12,3	19,5	17,2	15,1	19,2	17,09
Madrid	08 221	21,2	16,1	19,4	21,4	14,9	16,0	18,35
Essen	10 410	24,7	17,4	20,3	14,9	15,7	19,9	19,10
Stuttgart	10 739	29,5	19,1	18,4	17,6	22,8	17,9	21,31
Wien	11 035	25,3	23,5	24,3	21,6	12,7	19,2	21,52
Payerne	06 610	28,7	20,1	26,1	20,6	23,2	19,5	23,28
Greifswald	09 184	29,2	18,8	20,8	27,1	21,0	22,6	23,54
Lindenberg	09 393	29,5	22,0	22,1	20,9	18,2	27,9	23,77
Hannover	10 338	21,7	19,9	15,9	25,0	30,5	28,2	24,05
Gibraltar	08 495	26,4	28,2	25,9	23,6	26,0	23,8	25,70
Schleswig	10 035	24,5	19,6	24,7	46,7	11,3	18,0	26,54
Trappes	07 145	34,7	19,9	30,7	37,3	22,1	32,7	30,25
Prag	11 520	29,3	29,2	19,5	45,3	21.4	36,8	31,51
Lyon	07 481	30,6	46,8	35,6	22,7	32,6	24,6	33,11
Belgrad	13 275	34,7	43,0	37,6	--	--	8,3	33,67
Uccle	06 447	44,4	25,2	34,8	32,3	26,4	36,2	33,83
Brest	07 110	42,1	28,3	21,7	53,1	28,0	25,1	34,83

Tab. 4

Standard Deviation, gpm

100 hPa level, 00 UTC

2.2.2 Standard Deviation, 12 UTC

The figures of the standard deviation of day ascents are shown on the following page in table 5.

It is apparent that the station Crawley achieved the same excellent values in day ascents as at OO UTC.

The smallest and largest RMS values of the table are in the relation of ca. 1 : 3.

2.2.3 Day/Night Difference of the Standard Deviations

These figures have been compiled in table 6. The smaller the values, the better is the ability of the station to reproduce its measurements in day and night.

The larger figures of the table have positive signs, with a few atypical exceptions. Normally the scatter error is larger at 12 UTC than at OO UTC, as an effect of the radiation error.

The smallest and largest RMS value of the day/night difference of the standard deviation is 2.3 gpm and 15.4 gpm. The figures are in a relation of ca. 1 : 7.

AFE München

Station		1987						
Name	No	JAN	FEB	MAR	APR	MAY	JUN	RMS value
Crawley	03 774	16,5	13,4	17,5	14,4	12,5	13,2	14,70
Camborne	03 808	15,9	15,0	16,7	12,6	11,6	17,1	14,96
De Bilt	06 260	16,2	14,9	19,2	15,0	14,8	12,7	15,59
Rom	16 245	20,7	--	--	13,4	10,9	16,3	15,75
München	10 868	21,4	16,7	19,3	16,6	12,4	15,0	17,14
Udine	16 044	18,1	15,2	13,1	11,5	20,7	21,8	17,16
Essen	10 410	14,8	16,6	20,1	21,8	15,4	17,4	17,86
Madrid	08 221	19,0	22,6	19,5	25,0	21,6	17,1	20,96
Mailand	16 080	16,2	17,3	18,6	12,7	37,3	16,4	21,33
Stuttgart	10 739	24,0	24,5	21,2	19,4	16,0	22,7	21,50
Hannover	10 338	20,2	16,4	15,4	19,6	21,5	34,0	22,05
Wien	11 035	30,7	24,1	26,3	26,5	11,3	12,8	23,13
Prag	11 520	35,4	25,7	22,9	16,6	18,3	28,1	25,29
Schleswig	10 035	20,2	35,4	23,4	21,2	17,3	32,6	25,89
Lindenberg	09 393	32,1	15,6	32,0	29,8	24,3	17,9	26,13
Brest	07 110	33,3	27,1	26,6	26,8	21,8	26,2	27,17
Greifswald	09 184	26,0	22,5	26,7	23,9	36,3	30,7	28,07
Gibraltar	08 495	26,7	29,7	29,4	27,8	28,9	25,8	28,09
Trappes	07 145	40,3	28,4	28,9	26,8	33,8	41,2	33,72
Payerne	06 610	48,1	29,1	28,6	26,9	39,0	30,6	34,54
Lyon	07 481	46,6	30,7	36,9	34,9	31,8	33,2	36,07
Belgrad	13 275	32,4	45,4	46,6	--	--	--	41,96
Uccle	06 447	36,2	47,7	39,3	41,0	29,7	63,4	44,18

Tab. 5 Standard Deviation, gpm

100 hPa level, 12 UTC

Station		1987						
Name	No	JAN	FEB	MAR	APR	MAY	JUN	RMS value
Crawley	03 774	2,4	-0,5	1.2	-0,2	1.0	-4.7	2.26
Camborne	03 808	-0,8	-1,6	0,6	-4,2	-0,3	4,7	2,69
Gibraltar	08 495	0,3	1,5	3,5	4,2	2,9	2,0	2,73
De Bilt	06 260	-0,7	-0,8	5,6	1,4	3,8	-5,2	3,56
München	10 868	0,4	1,1	5,8	1,5	-1,0	6,8	3,75
Wien	11 035	5,4	0,6	2,0	4,9	-1,4	-6,4	4,09
Madrid	08 221	-2,2	6,5	0,1	3,6	6,7	1,1	4,21
Stuttgart	10 739	-5,5	5,4	2,8	1,8	-6,8	4,8	4,83
Rom	16 245	4,3	--	--	-1,0	-7,2	4,7	4,83
Essen	10 410	-9,9	-0,8	-0,2	6,9	-0,3	-2,5	5,04
Hannover	10 338	-1,5	-3,5	-0,5	-5,4	-9,0	5,8	5,14
Belgrad	13 275	-2,3	2,4	9,0	--	--	--	5,54
Lindenberg	09 393	2,6	-6.4	9,9	8,9	6,1	-10,0	7,77
Udine	16 044	4,9	-5,3	1,7	-9,2	12,7	7,9	7,78
Greifswald	09 184	-3,2	3,7	5,9	-3,2	15,3	8,1	7,84
Trappes	07 145	5,6	8,5	-1,8	-10,5	11,7	8,5	8,43
Mailand	16 080	-1,9	5,0	-0,9	-4,5	22,2	-2,8	9,58
Lyon	07 481	16,0	-16,1	1,3	12,2	-0,8	8,6	11,11
Brest	07 110	-8,8	-1,2	4,9	-26,3	-6,2	1,1	11,79
Payerne	06 610	19,4	9,0	2,5	6,3	15,8	11,1	12,08
Prag	11 520	6,1	-3,5	3,4	-28,7	-3,1	-8,7	12,71
Schleswig	10 035	-4,3	15,8	-1,3	-25,5	6,0	14,6	13,96
Uccle	06 447	-8,2	22,5	4,5	8,7	3,3	27,2	15,38

Tab. 6 Day/Night Difference (12 UTC minus 00 UTC)
of Standard Deviation, gpm
100 hPa level

2.3 Sum of Errors

In this paragraph a figure shall be obtained forming a sort of average of the results of the six error criteria. The arithmetical average would have been suitable for this purpose. Also a differentiation in the weight of the individual errors would have been possible. However, in order to apply a procedure as simple as possible the sums of the RMS values of the tables 1 to 6 have been calculated in table 7.

The smallest sum is 57 gpm, the largest value ist 213 gpm. The figures are in a relation of approximately 1 : 4. The large difference indicates that improvements may be possible.

Station Name	No	value of RMS , gpm						Sum of RMS
München	10 868	9.95	7.43	3.78	14.95	17.14	3.75	57.00
Essen	10 410	19.23	9.88	10.87	19.10	17.86	5.04	81.98
Lindenberg	09 393	8.85	4.47	12.36	23.77	26.13	7.77	83.35
De Bilt	06 260	15.96	14.68	18.78	14.96	15.59	3.56	83.53
Greifswald	09 184	8.36	15.02	9.91	23.54	28.07	7.84	92.74
Gibraltar	08 495	12.08	11.05	14.45	25.70	28.09	2.73	94.10
Stuttgart	10 739	25.66	24.37	7.99	21.31	21.50	4.83	105.66
Prag	11 520	10.96	12.48	15.44	31.51	25.29	12.71	108.39
Udine	16 044	24.76	18.64	25.09	15.33	17.16	7.78	108.76
Crawley	03 774	38.18	33.19	6.76	14.85	14.70	2.26	109.94
Hannover	10 338	27.08	26.06	5.65	24.05	22.05	5.14	110.03
Madrid	08 221	28.31	25.45	16.33	18.35	20.96	4.21	113.61
Schleswig	10 035	22.74	14.86	11.66	26.54	25.89	13.96	115.65
Mailand	16 080	26.07	20.73	23.95	17.09	21.33	9.58	118.75
Camborne	03 808	42.45	37.58	5.90	15.23	14.96	2.69	118.81
Rom	16 245	22.16	25.25	38.43	15.32	15.75	4.83	121.74
Payerne	06 610	38.05	19.94	20.18	23.28	34.54	12.08	148.07
Wien	11 035	41.92	10.95	48.13	21.52	23.13	4.09	149.74
Trappes	07 145	40.44	7.18	34.75	30.25	33.72	8.43	154.77
Brest	07 110	38.66	11.13	40.21	34.83	27.17	11.79	163.79
Lyon	07 481	43.55	11.97	36.94	33.11	36.07	11.11	172.75
Belgrad	13 275	21.69	35.07	50.29	33.67	41.96	5.54	188.22
Uccle	06 447	55.91	31.16	33.05	33.83	44.18	15.38	213.51
Tab. No		1	2	3	4	5	6	
Parameter		Bias 00 UTC	Bias 12 UTC	Day/Night Difference of Bias	Standard Deviation 00 UTC	Standard Deviation 12 UTC	Day/Night Difference of Standard Deviation	

Tab. 7 Survey
January - June 1987,
100 hPa

3. Summary

* On the basis of the data provided by the ECMWF the following 6 characteristical values of the 100 hPa level have been compiled of 23 selected upper-air stations:

- Bias,	00 UTC	in table 1
- Bias,	12 UTC	in table 2
- Day/Night Difference of Bias		in table 3
- Standard Deviation	00 UTC	in table 4
- Standard Deviation	12 UTC	in table 5
- Day/Night Difference of Standard Deviation		in table 6

* For the first 6 months of 1987 the square average, i.e. the RMS value of each station, was determined for each one of these errors. The order of the stations in the tables 1 to 6 has been determined according to the quantity of the RMS value. The tables indicate that the European radiosondes have widely varying errors. The relation between the smallest RMS value and the largest one was

ca. 1 : 2	in table 4	(standard deviation, 00 UTC)
ca. 1 : 13	in table 3	(day/night difference of bias).

* In table 7 the sums of the RMS values of the tables 1 to 6 have been formed. The smallest sum is 57 gpm, the largest sum reaches 213 gpm.

* Each station can gather from the tables where its strong and weak points are and which measures would be appropriate to reduce the errors.

* Therefore I would like to recommend the following action. Every six months a table similar to No 7 should be distributed by the ECMWF for the levels 300, 100 and 30 hPa.