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ACCURACY, REPRODUCIBILITY, AND VERTICAL RESOLUTION OF DATA FROM RADIOSONDES

Hans Richner

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16. Abstract

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ACCURACY, REPRODUCIBILITY, AND VERTICAL RESOLUTION OF DATA FROM RADIOSONDES

/42*

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SUMMARY: In a comparison of three radiosonde-systems typical data deviations as well as their reproducibility could be determined. Basic considerations regarding a possible vertical resolution are followed by a suggestion as to how the ascent velocity of the balloon could be utilized to determine vertical winds.

1. INTRODUCTION

In the fall of 1978 the radiosonde systems used in Switzerland were compared to one another under operating conditions. This was done primarily with a view to ALPEX, the data program within the framework of the GARP sub-program on airflow over and around mountains, after Zimmermann (1978) had pointed out serious deviations encountered in various sonde systems. In addition to the actual results of the comparison flight, which shall be discussed here only briefly (see Phillips et al., 1980), valuable information was gained from the investigation of the sonde systems in the field and in the laboratory which could be of basic importance for the utilization of such measuring systems. Here an attempt is to be made to point out the limitations of

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resolution, but also of up till now unused potentials of the radiosondes generally available today. Measurements and analyses with the Vaisala RS-18, the VIZ 1392, and the Swiss sonde were conducted jointly by the Swiss Meteorological Institute (Joss, Rieker, and Gutermann), by the Geographical Institute of the ETH (Ohmura) and by the Laboratory for Atmosphere Physics of the ETH (Phillips and Richner).

2. ACCURACY AND REPRODUCIBILITY

The average deviations of the temperatures of the various sondes were maximally 2.5 K at a 10 mb altitude (figure 1a). The positive deviation of the VIZ sonde could be identified as a radiation effect which will be taken into consideration in the future during the assessment. The pressure deviations (figure 1b) were 1 mb on the average. An exception was found in the Swiss sonde in the range of 100 mb where the deviations had values up to 3 mb. This resulted from a deficient temperature compensation of the capsule used in this range; the deficiency has been corrected in the meantime. The fact that errors in pressure measurement generally have no great effect is well known; the deviations of the geopotentials depicted in figure 1c reflect only differences in temperature. If one takes into account the great difficulties encountered in the determination of /43 moisture, the deviations shown in figure 1d appear to be acceptable. Below 500 mb the differences are always less than 10%, above it about 15%.

Reproducibility measurements for the same sonde type could only be made with the VIZ sonde; the results are summarized in Table 1. As can be seen, the temperature calibration was obviously deficient during the double ascent No. 2 which fact also affected the moisture measurement.

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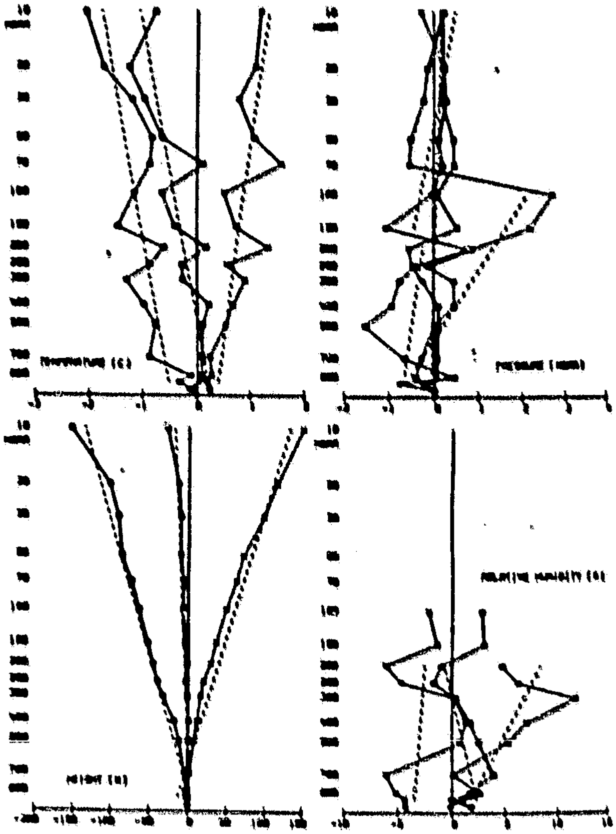

Figure 1: Average deviations of the data from different sonde systems from about 20 ascents per sonde type. (*——*: Swiss sonde, x——x: VIZ o——o: Vaisala).

Table 1 Reproducibility of the data obtained from the VIZ sondes

	No.	P	T	U
average deviation	1	0.9	0.4	2.8
	2	0.5	1.8	20.9
	3	1.1	0.2	7.8
average quadratic deviation	1	0.87	0.35	0.89
	2	0.87	0.57	1.6
	3	0.95	0.58	2.5

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3. VERTICAL RESOLUTION

Each sensor had a certain inertia which is generally designated as time constant (strictly speaking this designation is only correct if the action of the sensor is described by a differential equation of first order). The time constant τ of the temperature sensor, e.g., is determined primarily by the heat capacity of the sensor and by the heat transfer resistance between sensor and environment. While the heat capacity is constant, the heat transfer resistance depends primarily on the ventillation speed u and the density of the surrounding air, i.e., on the pressure p and the temperature T. We obtain:

$$\tau = \tau_0 \, [(u_0/u)(p_0/p)(T/T_0)]^{\frac{1}{2}} \qquad (1)$$

whereby τ_0 represents the time constants for u_0 and T_0.

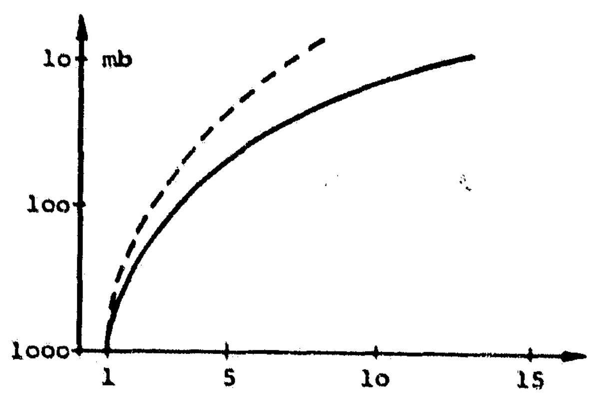

Figure 2: Relative increase of the time constant (---) resp. of the vertical resolution (———) limiting it as a function of the altitude.

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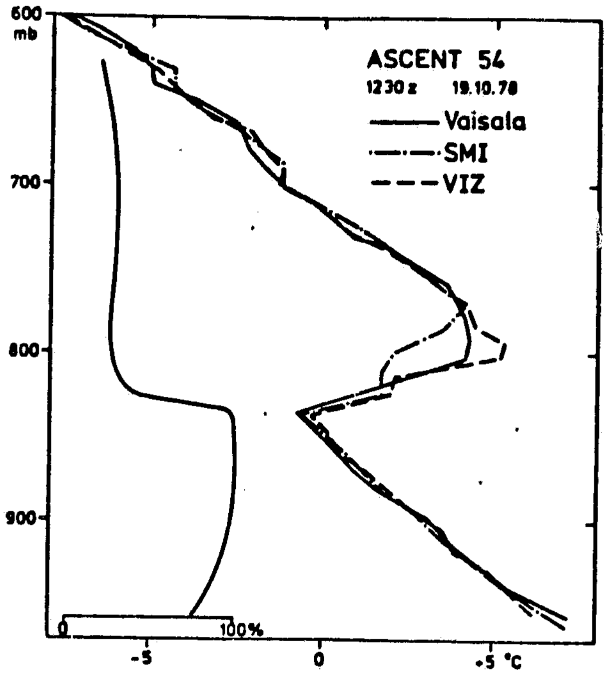

Figure 3: An inversion as it was picked up by three different sondes with the same balloon (SMI: Swiss sonde). The moisture profile on the left is averaged and smoothened.

For the sondes under consideration the time constant of the temperature sonde is about 5 sec (u_0 = 5 m/s, p_0 = 1000 mb, T_0 = 293 K). Under the assumption that the ascent velocity of the balloon increases from about 5 m/s near the ground to about 8 m/s at an altitude of 10 mb, the time constant takes on a value of 12 sec at 100 mb and a value of about 35 sec at 10 mb (see figure 2). If one multiplies this value with the given ascent velocity, then one obtains for the maximum possible vertical resolution near the ground 25 m, 80 m at 100 mb, and 300 m at 10 mb.

Most of the sonde types do not transmit the data continuously, but in certain intervals. This interval need not be shorter than the time constant of the sensor, on the other hand it should not be appreciably longer since otherwise there is a danger that the first transmitted value is a random one since, because of the short time constant, it no longer has the value determined during the last transmission. For the systems investigated the scanning rate differed; the manufacturer of each system tried to effect a compromise: the Vasala sonde transmits a data point every 8 seconds, the Swiss sonde every 30 sec, and the VIZ sonde every 20 seconds below 100 mb; above 100 mb this invertal continuously increases until it reaches a value of about 2 minutes at 10 mb. Depending on altitude and type of sonde the maximum obtainable resolution is determined sometimes by the sensor, sometimes by the scanning rate. Figure 3 shows the different ways in which an inversion is /44 recorded by the three different sondes in the same balloon. The pronounced deviation of the Swiss sonde designated by SMI can be attributed to the fact that water droplets formed at the sensor which increased the time constant.

For the time constants of the moisture sensors analogous considerations apply as those for the temperature sensors. However, the time constant is dependent here additionally on the pressure of the water vapor.

From the above statements it is clear that a short time constant is appropriate only when the scanning rate of the system is correspondingly high since otherwise the measurement becomes a random one. Whether a high vertical resolution is at all meaningful, naturally depends on the purpose for which the data are to be used. For the TEMP reports used in weather service, e.g., the resolutions shown are more than sufficient. If one is conducting special investigations with very high-resolution radio sondes, one additionally encounters a problem which has long been known from boundary layer investigations; unfortunately there is no possibility to conclude solely from the ascent profile whether certain variations of a measured value correspond to a real horizontal layer formation or whether they are caused by turbulence and thus are random values.

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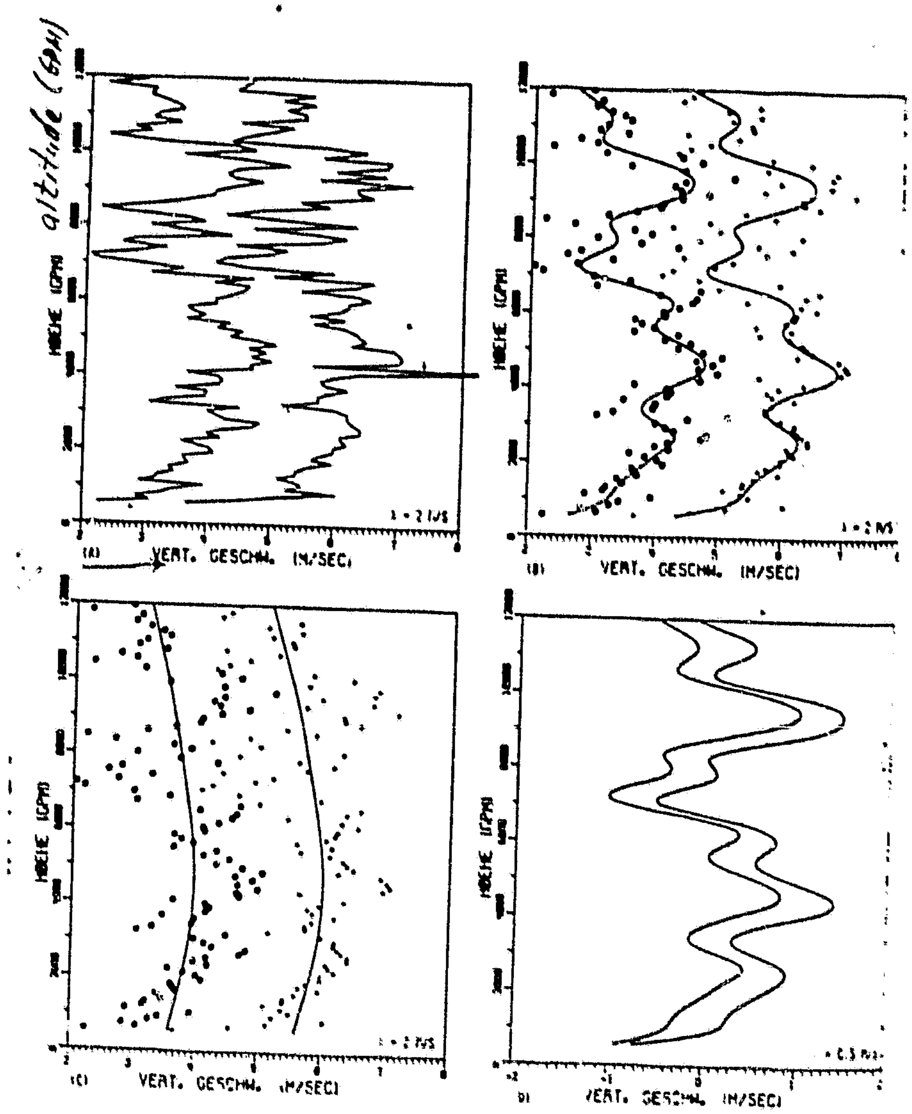

Figure 4: Ascent velocity of two sondes on the same balloon. (A) unsmoothened, (B) lightly smoothened, (C) greatly smoothened data, (D) difference between (B) and (C). The data points and curves of the one ascent are each plotted displaced by 2 m/s (in (D) by 0.5 m/s).

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4. DETERMINATION OF VERTICAL WINDS

According to theory a balloon accelerates during constant solar radiation - that is above the clouds - its vertical velocity monotonically with increasing altitude (see e.g. Morris, 1975). However, it is shown in practice that the ascent velocity can vary greatly. These velocities can be determined quite reliably from the layer thicknesses, i.e., the differences in the geopotential; the accuracy is at least 1% whereby the uncertainties of the virtual temperature and pressure measurement are contained therein. The time which elapses until the balloon has moved through the corresponding layer, can still be determined considerably more accurately and thus represent no accuracy-limiting factor.

Figure 4a shows the ascent velocity of the balloon as it was obtained independently from the data of two sondes from the same balloon. For a clearer picture the velocity profile of the one /45 sonde was drawn displaced by 2 m/s. Figure 4b shows the smoothened velocity profiles. With the use of modern smoothening procedures (here, e.g. cubical spline), the degree of smoothening can be controlled continuously; in extreme cases the original data are approximated by a regression straight line.

It lies near to interpret a greatly smoothened curve (figure 4c) as a real ascent velocity of the balloon, and to consider deviations of the weakly or not at all smoothened ascent velocity as disturbances which arise from the vertical movements of the air masses. (Here the self ascent velocity decreases with altitude since two sondes had to be carried upward; normally the velocity increases). As shown by the double ascent, (figure 4d) these vertical winds can be determined accurately to about several 10 cm/s. Calculations also show that the errors caused by the mass inertia of the balloons are of the order of magnitude of 10 cm/s and are thus negligible; however, they can also be taken

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into account in the calculations if so desired.

To what extent the vertical wind can be utilized in weather service, must still be investigated more closely. The greatest problem certainly rests in the need to transfer the velocity measured at a point on the synoptic scale. It would be desirable if, for instance, during ALPEX this question could be investigated in a sonde network as dense as possible. In the meantime the theoreticians would have an opportunity to check whether and how these data interesting primarily from a measuring standpoint could be used in practice.

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