Photogrammetrische Woche 1981
Institut für Photogrammetrie
Schriftenreihe, Heft 8, 1982

RESULTS OF NEW EXPERIMENTS WITH STATOSCOPE

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1. Introduction

The use of statoscope-measurements in the adjustment of photogrammetric blocks has proved to be a most universal and economic method by which the number of vertical control points required for small scale mapping projects can be drastically reduced.

The statoscope instrument is a particularly sensitive differential barometer. During a photo-flight it indicates continuously the differences of pressure between an unknown isobaric surface and the actual position of the aircraft. With each exposure the momentary indication of the instrument is recorded onto the frame of film.

The statoscope readings can be converted to height-differences dz_{stat} with the help of the absolute pressure and temperature in the flying height and a calibration constant of the statoscope instrument. These height-differences represent a height profile along the camera air-stations of a strip based on an isobaric surface with unknown altitude and tilt.

Within the range of one flight strip the isobaric surface can be assumed to be linear. Therefore the statoscope-measurements of one strip are usually treated as one so-called statoscope-profile.

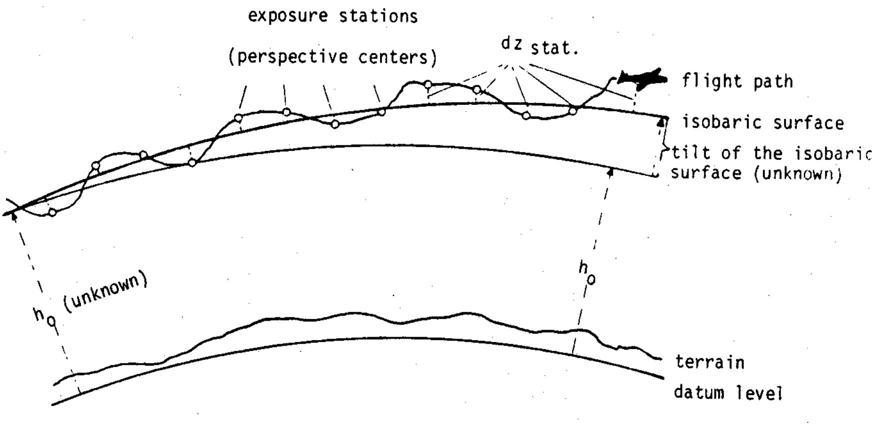


Fig. 1: Principle of the statoscope measurements

As described in |1|, the statoscope profiles can be adjusted simultaneously with the strip or block adjustment. The unknown altitude- and tilt-parameters of the isobaric surface will be determined by such an adjustment.

2. Previous results of combined adjustments with statoscope-data

2.1 Theoretical studies have shown and practical tests have confirmed with regard to vertical accuracy that the propagation of errors in photogrammetric blocks is reduced drastically by the combined adjustment of statoscope-profiles, thus allowing the bridging of long distances without vertical control points.

The theoretical height accuracy has been studied by H. KLEIN for blocks consisting of 10 strips and 10, 20, 40, 60 and 80 models per strip, respectively (unpublished, see also |2|).The following project parameters were assumed:

		wide-angle	super-wide-angle
photo scale	:	1:50,000	1:50,000
σ_Z of model-measurements	:	20 µm in the photo	20 µm in the photo
σ of the statoscope height differences	:	0.85 m	0.58 m
flying height	:	7,650 m	4,250 m
forward overlap	:	60 %	60 %
side overlap	:	20 %	20 %
location of control points	:	one chain of vertical control points at either side of the block	

The resulting theoretical height accuracies of the adjusted blocks are summarized in table 1:

block size: Models km²	10x10 90x45	10x20 90x90	10x40 90x180	10x60 90x270	10x80 90x360
wide-angle (h=7650 m)					
$\sigma_{Z_{mean}}$	1.2 m	1.4 m	1.5 m	1.5 m	1.6 m
$\sigma_{Z_{max}}$	1.9	2.1	2.3	2.4	2.5
super-wide-angle (h=4250 m) $\sigma_{Z_{mean}}$		1.4	1.5	1.6	1.6
$\sigma_{Z_{max}}$		2.1	2.3	2.5	2.6

Table 1:
Theoretical height accuracy of blocks with combined adjustment of statoscope-measurements

The table shows that the vertical accuracy of the adjusted points deteriorates only little when the bridging distances are enlarged.

2.2 The above results have been essentially confirmed by practical tests of the height accuracy using field measured check points: The two diagrams of figure 2 show vertical accuracy results of the OEEPE test block "Oberschwaben" with and without the use of statoscope measurements, as function of bridging distance i (see H. KLEIN |3|).
W. FAIG |4| got similar results from the Halifax-test-block (see fig. 3). Other investigations |5|, |6| gave corresponding results.

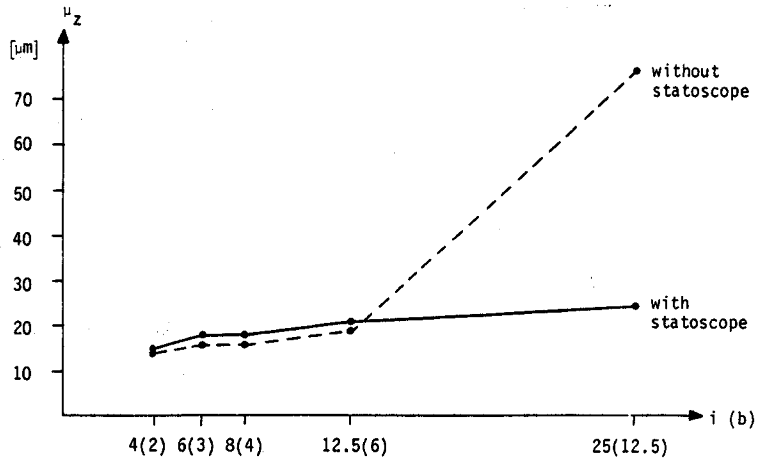
3. Accuracy of the statoscope measurements

3.1 The previous investigations and the general practical application of the statoscope all refer to small scale mapping,as the accuracy of the statoscope measurements was assumed to be in the range of 1 m and 1.5 m or beyond. In addition, the accuracy ratio between the photogrammetric and the statoscope measurements becomes poorer with larger photo scales (see fig. 4). The vertical accuracy of photogrammetrically measured points (converted to ground units) is linearly dependent on the photo scale, i.e. decreases linearly with the flying height. Whilst the accuracy of the statoscope measurements and the instrument's sensitivity (here for example 0.7 m per scale unit at sea level) are dependent on the absolute air pressure and thus cannot retain the barometric measuring accuracy at sea level.

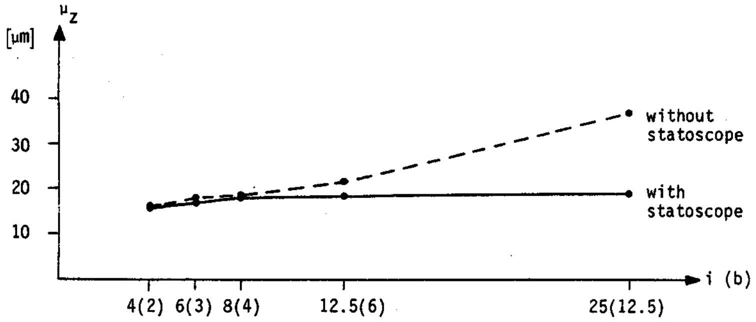
The statoscope instruments which are available on the market, for the time being, have been designed and developed 25 or more years ago, aiming at the above mentioned accuracy range|7|. Since, they have been used rather infrequently in photogrammetric practice |9|. The reason is, in our opinion, that the use of statoscope data became really effective not until the recent possibility of their introduction into the combined adjustment.

Fig. 2:
OEEPE test Oberschwaben

Height accuracy with and without statoscope-measurements



Wide-angle block Frankfurt
(1:28,000 photo scale)



Super-wide-angle block The Hague
(1:28,000 photo scale)

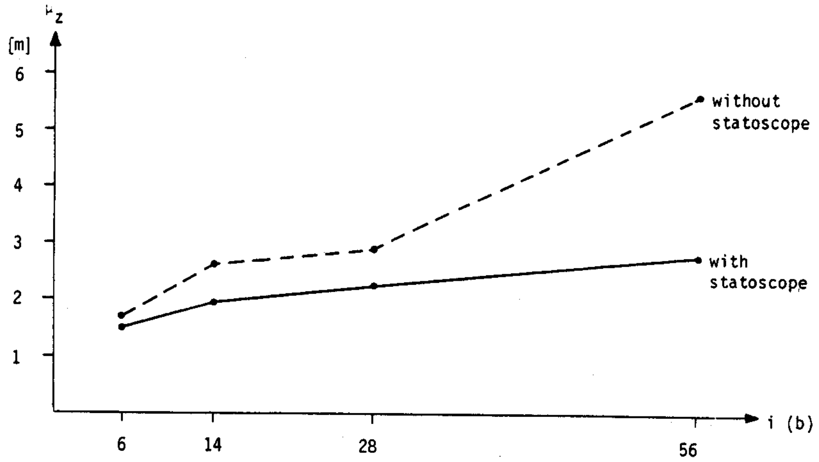


Fig. 3:
Test block Halifax
(1:33,000 photo scale)
Height accuracy with and without statoscope-measurements

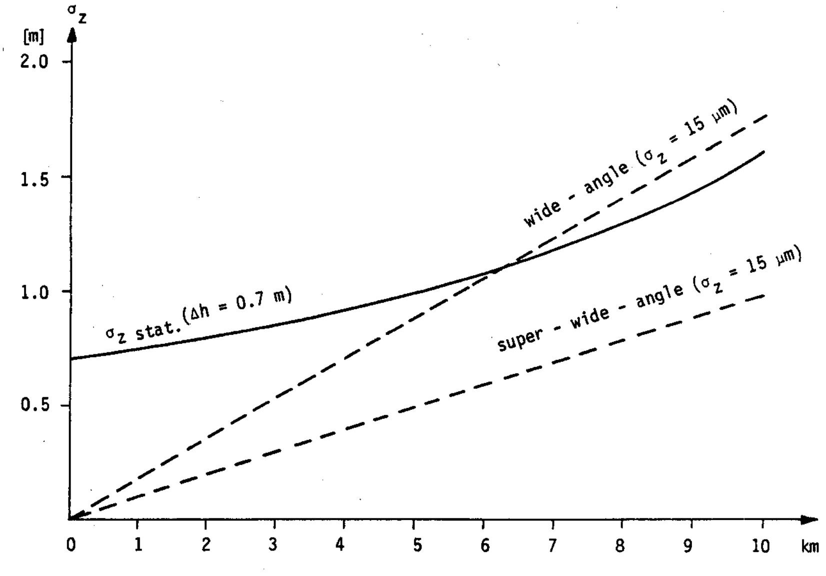


Fig. 4:
Height accuracy of photogrammetric model measurements and of statoscope-measurements dependent on the flight height

3.2 The great number of well distributed vertical control points of the test block "Oberschwaben" allowed to estimate the accuracy of the statoscope-measurements themselves |8|.

For that purpose the statoscope-profiles were transformed and compared with the (almost true) z-coordinates of the perspective centers as obtained from a fully controlled block adjustment. The root mean square values m_{stat} of the differences (interpreted as standard errors of the statoscope-measurements) were determined for all strips:

strip	wide-angle h_{abs} = 4990 m m_{stat}	super-wide-angle h_{abs} = 3085 m m_{stat}
1	0.94 m	1.08 m
2	1.20	1.12
3	0.59	0.26
4	0.79	0.30
5	0.63	0.31
6	0.72	0.27
7	0.65	0.79
8	1.30	1.16
9	0.58	1.30
10	0.87	1.10
11	0.91	0.67
12	1.18	0.82
13	0.80	0.47
14	0.91	0.44
15	0.80	0.34
	0.89	0.79

The r.m.s. values over all 15 strips being 0.89 m (wide-angle, flying height 4990 m) and 0.79 m (super-wide-angle, flying height 3085 m), respectively, were unexpectedly small. Really surprising, however, were the r.m.s. values of some of the super-wide-angle strips, in the range of only 0.26 - 0.34 m (5 strips) and - 0.47 m (7 strips), respectively.

3.3 These results supported the conjecture that the measuring system of the statoscope (including the physical properties of the isobaric surface) might be far better than was assumed until then.

If there could be found a way to improve the statoscope measuring system at low altitudes to a reliable and consistent accuracy of about 0.5 m or better, the statoscope could be used for medium to large scale mapping purposes also.

Therefore, the Institute of Photogrammetry of Stuttgart University organized in 1979 and in 1981 controlled statoscope test flights in order to check the accuracy limit of the statoscope measuring system by using a more sensitive statoscope.

Previously, the reading accuracy at the dial of the Zeiss statoscope S 2 was limited to about 20 cm or more, at sea level. It was related to the sensitivity of the instrument which could only be adjusted to a height difference of approx. 0.8 m per scale unit, in order to maintain a sufficient measuring range of the instrument.

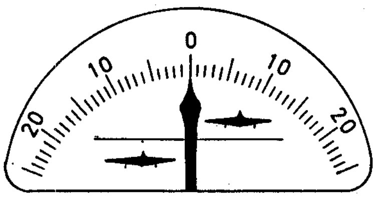


Fig. 5: Former dial of the statoscope Zeiss S 2 (enlarged)

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4. Statoscope test flights "A 81 Herrenberg-Oberndorf" 1979 and 1981

4.1 For the test flight in 1979 the statoscope S 2 was equipped with a digital read-out by the Carl Zeiss Company, Oberkochen. The three-digit indicator allowed adjustment of the sensitivity to approx. 5 cm per digit without limiting the measuring range. The measuring system of the statoscope was, however, not changed.

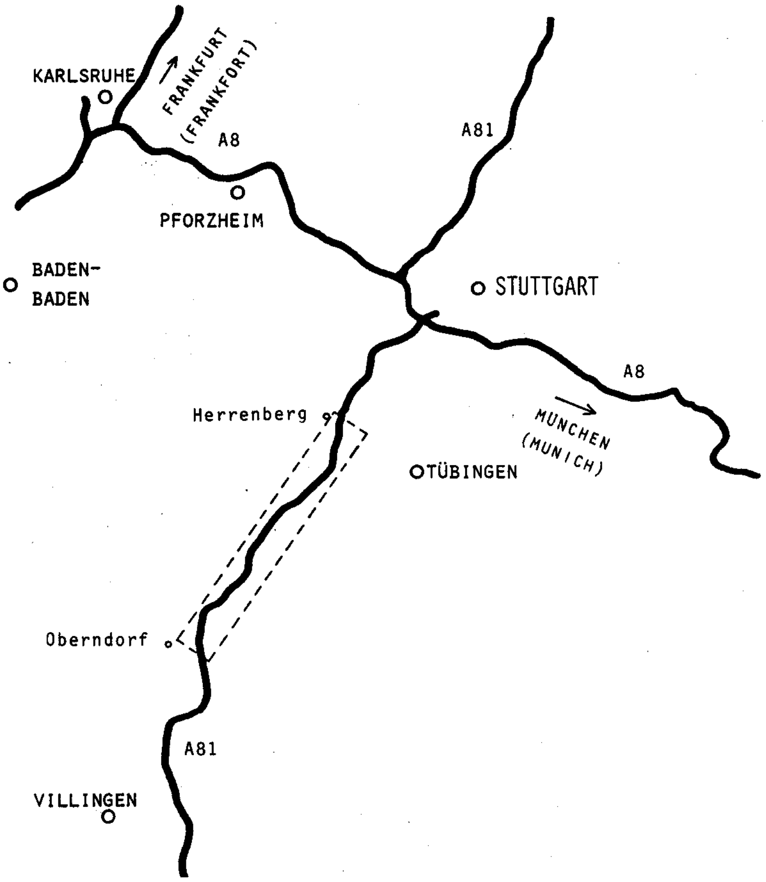

Fig. 6:
Test flight
"A 81 Herrenberg-Oberndorf",
strip area

Description of the test flight 1979:

area	:	Autobahn A 81 Herrenberg-Oberndorf (km 610-650)
photo scale	:	1:20,000; h_{rel} = 3080 m, h_{abs} = 3580 m
date	:	August 5th, 1979, 9.15 - 9.40 a.m.
contractor	:	Photogrammetrie G.m.b.H., Munich
camera	:	Zeiss RMK 15/23
statoscope	:	Zeiss S 2 with 3-digits read-out
aircraft	:	Cessna 206
strips	:	2 (to and fro)
forward overlap	:	90 %
photos	:	90 per strip, 23 per strip with p = 60 %
mean distance between perspective centers (p = 90 %)	:	420 m ≅ 6.2 sec (250 km/h)
vertical control	:	480 points on the surface of the autobahn A 81, elevations interpolated by the Autobahnamt of Baden-Württemberg 48 points outside the autobahn area, elevations determined by field levelling

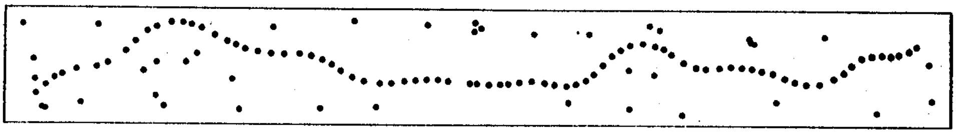

Fig. 7: Test flight "A 81 Herrenberg-Oberndorf" 1979, vertical control points

For the photogrammetric measurements (independent models) an analytical plotter Zeiss C 100 and a stereocomparator Zeiss PSK 2 were used. Each of the two strips of 90 % overlap were split into 4 strips of 60 % overlap, each. The 4 strips thus obtained from either flight were strongly interconnected by a great number of tie-points. The 4 strips were simultaneously adjusted as a block (with the program PAT-M 43 for independent models), making use of all available vertical control points.

Within the combined adjustment the statoscope data were treated with very low weight (0.001) to avoid any influence on the adjusted coordinates. Thus the root mean square values of the residuals represent directly a good estimate of the accuracy of the statoscope-measurements.

The results of the combined adjustments were:

	strips 1-4 forward flight	strips 5-8 reversed flight
σ_0 (vertical adjustment):	0.19 m	0.20 m
r.m.s. value of the residuals of the perspective centers in z:	0.12 m	0.12 m
r.m.s. value of the residuals of the vertical control points:	0.11 m	0.13 m
r.m.s. value of the residuals of the statoscope-measurements:	1.57 m	1.42 m

The results show that the accuracy of the statoscope-measurements was not improved by the use of a more sensitive indicator, but was significantly poorer compared with the "Oberschwaben" test.

4.2 The analysis of the residuals of the statoscope-measurements led to an interesting discovery which gives partly an explanation of those unexpectedly poor results (see fig. 8 and 9, appendix).

When studying the residuals, it became evident that in the case of a climbing flight path the sign of the residuals is positive and in the case of a descending flight path the sign is negative in most cases. This systematic effect is in the order of about 1.5 m.

It is not possible to find out definitely for each air station whether the flight path was actually climbing, descending or horizontal because the distance between adjacent perspective centers is still 400 m and the deviations of the aircraft from the mean flying height are relatively small. This means that the systematic error cannot be corrected rigorously.

Nevertheless the statoscope observations were approximately corrected by interpolating the slope of the flight path from the statoscope readings of the previous and the following exposure station.

The results of the correction were:

	strips 1-4	strips 5-8
systematic component of the residuals because of climbing and descending	1.04 m	0.94 m
r.m.s. value of the residuals of the statoscope-measurements after correction of the systematic error	1.17 m	1.07 m

There are still small effects of the above described systematic backlash error in the corrected profiles (see fig. 10 and 11, appendix). Obviously the approximate correction did not compensate for the systematic error completely.

4.3 In order to locate the source of the systematic error, the manufacturer of the statoscope tested the instrument using an elevator. Identical elevator positions were measured when riding up and down and the readings were compared. The test showed a systematic difference of the dial readings of about 0.8 former scale units which is equivalent to about 0.6 m height difference at 500 m above sea level. Thus, a major part of the backlash error seems to be caused by the measuring system of the statoscope instrument.

4.4 For a new test flight in 1981 the statoscope instrument was equipped by the manufacturer with an additional indicator showing momentary climbing and descending in order to determine the sign of the later correction of the backlash error. Climbing or descending is sensed in intervals of 0.5 seconds by comparing the momentary value of the statoscope reading with the value 0.5 seconds before.

The new test flight was essentially a repetition of the flight mission of 1979 with only some variations:

photo scale : 1:16,000; h_{rel} = 2,400 m, h_{abs} = 2,900 m
date : May 20th, 1981, 3.20 - 4.10 p.m.
contractor : Rheinische Braunkohlenwerke A.G., Cologne
aircraft : Partenavia P 68 B
strips (flights) : 4 (to and fro), with p = 90 % each
photos : 131 per strip, with p = 90 %; 33 per strip with p = 60 %
mean distance between perspective centers (p = 90 %) : 306 m $\cong$ 4,1 sec (270 km/h)
vertical control : 156 points on both border lanes of the autobahn A 81 in intervals of 500 m, signalized by the Autobahnamt of Baden-Württemberg
41 field levelled points (identical with 1979)

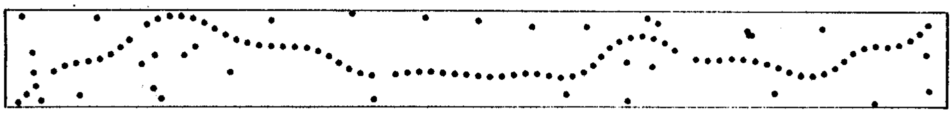

Fig. 12: Test flight "A 81 Herrenberg-Oberndorf" 1981, vertical control points

For one of the strips, with p = 90 %, the measurements with the analytical plotter Zeiss C 100 have been completed, to date, and investigated. Measurements and combined adjustment was done in the same way as described under 4.1. The following results of the combined adjustment using uncorrected statoscope-measurements were obtained:

σ_0 (vertical adjustment): 0.17 m
r.m.s. value of the residuals of the perspective centers in z: 0.08 m
r.m.s. value of the residuals of the vertical control points: 0.08 m
r.m.s. value of the residuals of the statoscope-measurements: 1.02 m

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4.5 When studying the residuals in connection with the flight path (see fig. 13, appendix), a backlash error becomes noticeable here also. The magnitude of the residuals and of the backlash error is about 40 % smaller as compared to the results of 1979. The slightly lower flying height is not considered an explanation. Considering that the same statoscope instrument was used as for the previous test flight, it can be assumed that different exterior conditions (such as aerodynamical and meteorological conditions or a different gauge system of the aeroplane) may be the reason for the above mentioned difference.

As a sign-criterion for correcting the backlash error again the statoscope readings of the previous and following air stations were used. The additionally installed indicator for climbing or descending proved not to be as effective as anticipated. Obviously the indicator failed in some cases or it was misled by small movements.

After correction of a backlash error of 0.59 m a r.m.s. value of the residuals of the statoscope-measurements of 0.84 m was obtained. The remaining residuals show still small local influences of the backlash error (see fig. 14, appendix). But also some additional systematic effects are noticed, such as a kind of inertia of the statoscope reading when changing from climbing to descending and vice versa.

The linearity of the isobaric surface seems to be sufficiently met. There is no evidence of a curvature of the statoscope profile. The tilts of the isobaric surfaces,as determined from the 1979 and 1981 test flights, were 0.2, 8.4 and 1.8 m per 40 km. The results indicate that the statoscope-measurements are, besides the backlash error, influenced by some additional systematic errors or effects. Additional investigations are necessary to detect the causes of those effects. Special attention should be paid to the exterior conditions during the photo flight and to the complete barometric measuring system of the aircraft.

5. Accuracy of combined strip adjustment with statoscope data

The investigations described in chapter 4 were all dealing with the accuracy of the statoscope-measurements themselves by making use of all available control points. In practical application, however, statoscope-measurements are treated as auxiliary data which are introduced as additional observations into combined block or strip adjustment. So, the really interesting question is how statoscope data with a given accuracy (here 0.84 m) influence or improve the vertical accuracy of the adjusted blocks or strips.

In order to give an experimental answer to this question, the photographs of the test flight 1981, measured so far, were used for a number of controlled strip-adjustments with and without the corrected statoscope data. The statoscope-measurements were given weight 0.08, according to their accuracy of 0.84 m in relation to the accuracy of the z-coordinates of the photogrammetric model points.

At first, the strip with 90 % forward overlap was split into 4 separate strips with p = 60 % each, which were adjusted separately. The 4 strips were then combined two by two, giving two strips with p = 80 %, and simultaneously adjusted. Finally the complete strip with p = 90 % was adjusted likewise. For each case adjustments with 4 different control point versions were computed both with and without use of statoscope data.

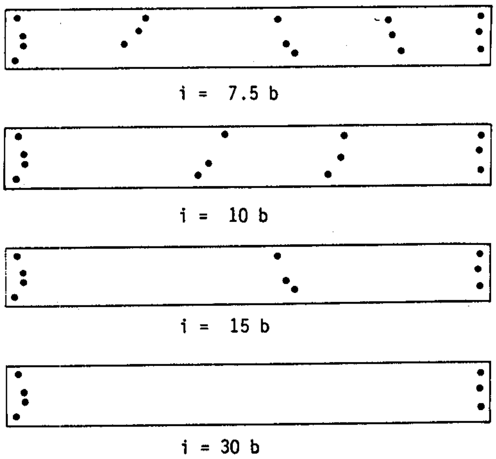
i = 7.5 b
i = 10 b
i = 15 b
i = 30 b

Fig. 15:
Test flight "A 81 Herrenberg-Oberndorf 1981",
vertical control point versions

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The remaining vertical control points were treated as check points to estimate the absolute height accuracy μz of the adjusted strips. The results are shown in table 2 (see appendix).

The diagrams of fig. 16 (see appendix) present the height accuracies μz as functions of the bridging distance i(b). The table confirms that the height accuracy of the strips after combined adjustment with statoscope data is obviously better than the accuracy of the statoscope data themselves.

The mean accuracy values of the strips with 60 % forward overlap, which is the usual case in practice, are 0.40 m and 0.61 m for the bridging distances of i = 7.5 b (≅ 10 km) and i = 30 b (≅ 40 km),respectively, which supercedes the accuracy of the statoscope data of 0.84 m by a factor 2 and 1.4, respectively. The result of previous investigations, that the height accuracy of photogrammetric blocks depends only weakly on the bridging distance when using combined adjustment of statoscope data, is here experimentally confirmed for strips, too. In this test, the combined strip adjustment with statoscope data gave for the largest bridging distance (i = 30 b) a vertical accuracy of 0.61 m, which is the same as the strip adjustment without statoscope data for the much shorter bridging distance of i = 7.5 b only.

By comparison, when bridging larger distances without statoscope data, the vertical accuracy deteriorates rapidly (0.9 m with i = 10 b, 1.6 m with i = 15 b), as is well known. The case with only one chain of vertical control points at the beginning and one at the end of the strip (i = 30 b) is not permitted without statoscope data, because of the uncontrolled bending of such poorly controlled strips. By the use of statoscope data the bridging distance between the vertical control points is not any more a severe accuracy limitation, as the strip or block accuracy is only slightly dependent on it, above a certain minimum threshold.

By contrast, without statoscope data, a certain bridging distance must not be exceeded in order to maintain obtaining a certain vertical accuracy of strips or blocks (here for instance i = 7-8 b for μz = 0.6 m).

With regard to the strips with 80 % and 90 % forward overlap, the results of this investigation confirm that the above mentioned relationships are even more valid. With statoscope data in those cases the vertical accuracy becomes slightly better and still more independent of the bridging distance whilst the results without statoscope data remain essentially the same as in the cases of 60 % forward overlap.

6. Conclusion

The preliminary results of the 1981 test flight confirm that the use of statoscope data in the combined adjustment suppresses the error propagation in the vertical adjustment of strips in a similarly effective way as is already known for blocks. It is not necessary to make very high demands on the accuracy of the statoscope-measurements themselves, as the height accuracy of the adjusted strips is better than the accuracy of the statoscope-measurements, which it should approach asymptotically in the case of very large bridging distances.

The use of statoscope instruments, as they are available on the market for the time being, seems to give an accuracy level which may recommend the application for medium and even large scale mapping at scales 1:10,000 or 1:5,000 (for 5 m, 2,5 m, or possibly even 2 m contour intervals).

The expected improvement of the accuracy of the statoscope-measurements, by modifying the instrument, to the range of 0.5 m or better,as suggested by some results of the "Oberschwaben" test,can obviously not be achieved without further steps. Additional investigations would have to show how the obviously still remaining systematic errors of the statoscope measuring system, including the atmosphere and the gauge system, could be eliminated or corrected.

Finally, it may be suggested to the manufacturers to develop new statoscope instruments, on the latest state of technology and which would exploit the physical potential of the method. As there is no other method to reduce the demand of vertical control points in a similarly effective and economical way, such a development of new instruments and the universal application of statoscope data for aerial triangulation is considered highly recommendable.

APPENDIX

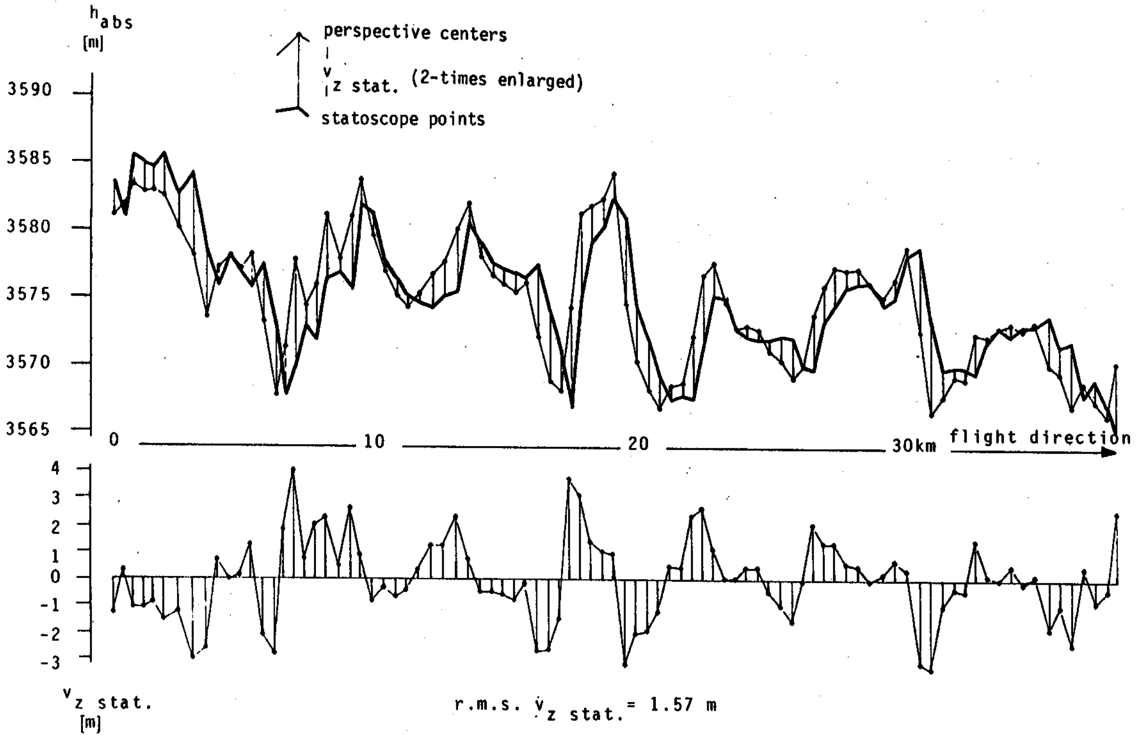

Fig. 8: Test strips 1-4, A 81 Herrenberg-Oberndorf (1979), Profile of the perspective centers with corrections v_Z of the statoscope-measurements (uncorrected)

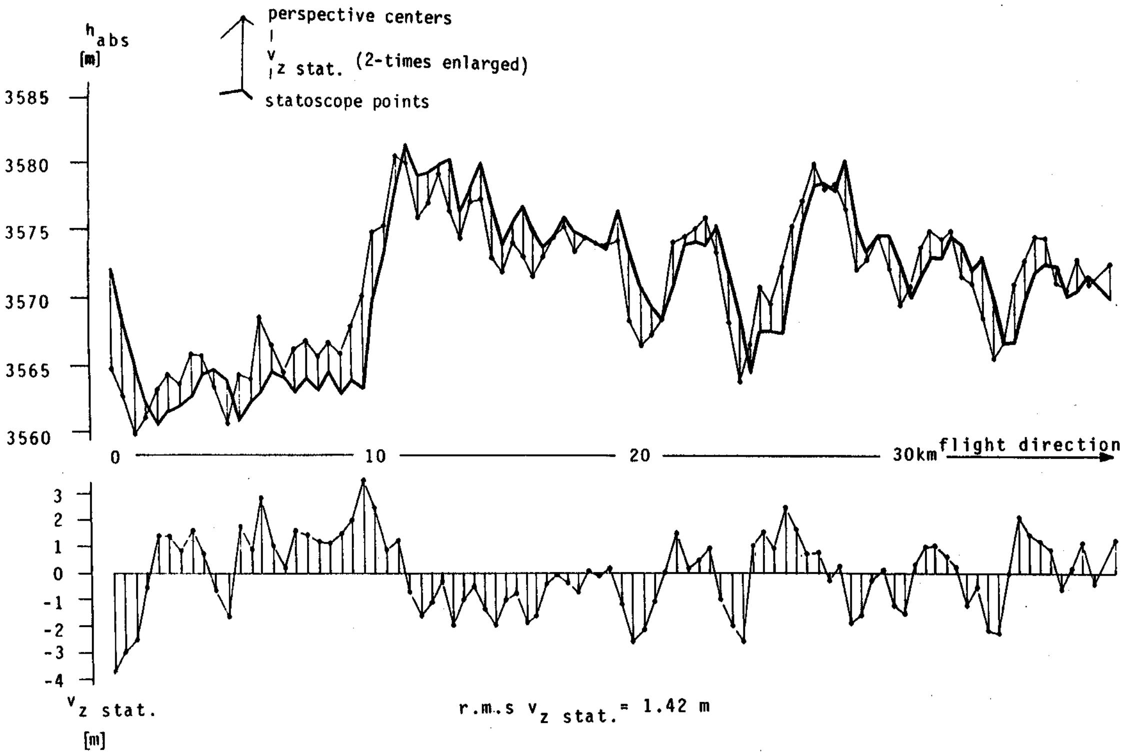

Fig. 9: Test strips 5-8, A 81 Herrenberg-Oberndorf (1979), Profile of the perspective centers with corrections v_Z of the statoscope-measurements (uncorrected)

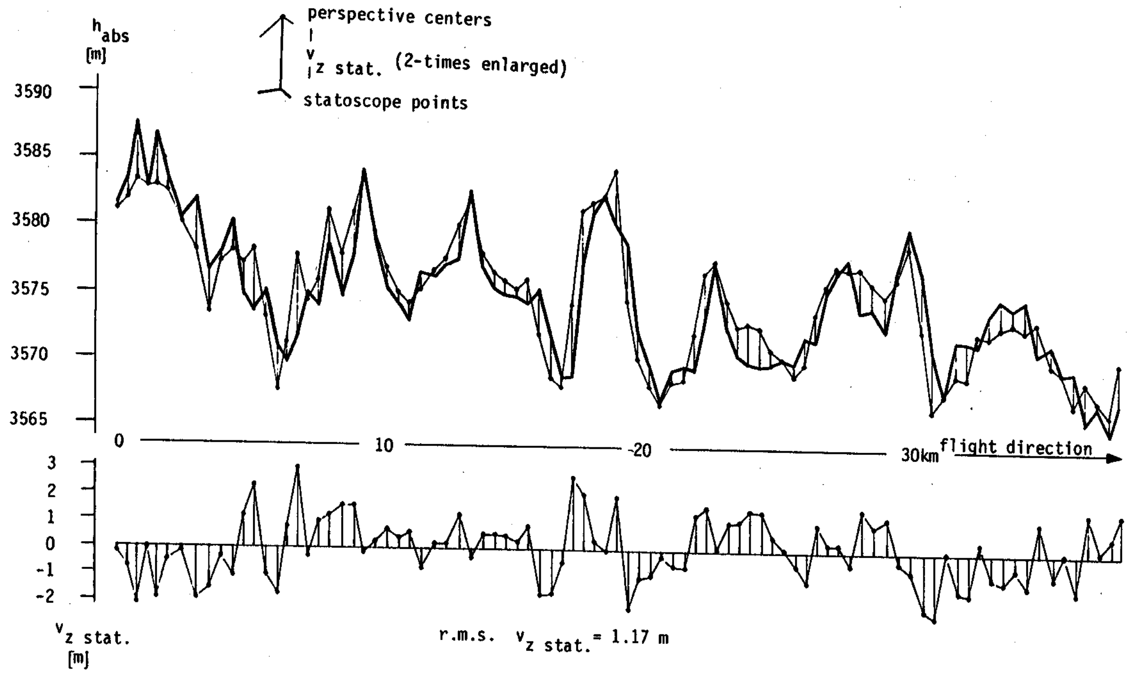

Fig. 10: Test strips 1-4, A 81 Herrenberg-Oberndorf (1979), Profile of the perspective centers with corrections v_z of the statoscope-measurements (corrected)

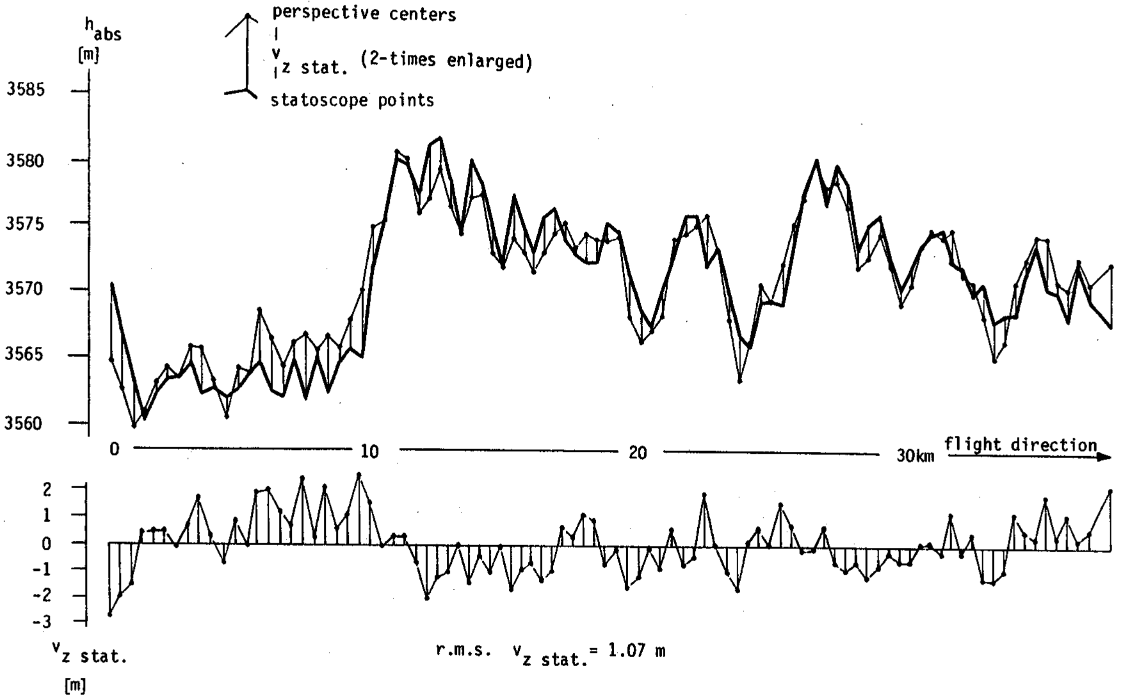

Fig. 11: Test strips 5-8, A 81 Herrenberg-Oberndorf (1979), Profile of the perspective centers with corrections v_z of the statoscope-measurements (corrected)

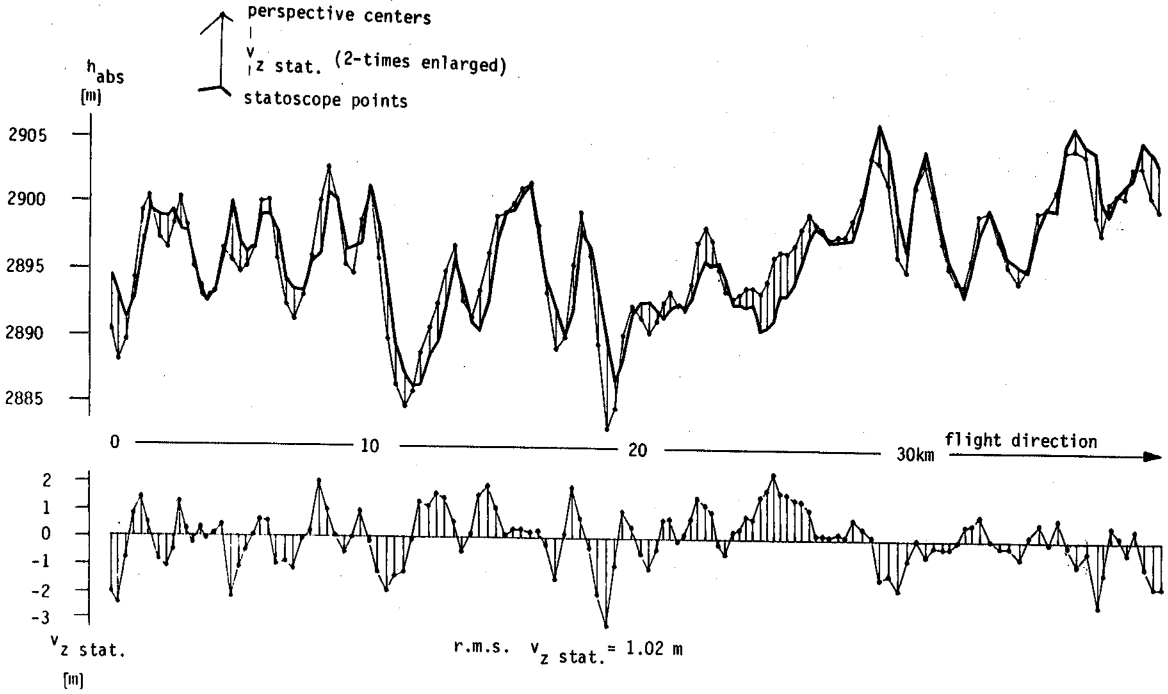

Fig. 13: Test strip A 81 Herrenberg-Oberndorf (1981), Profile of the perspective centers with corrections v_z of the statoscope-measurements (uncorrected)

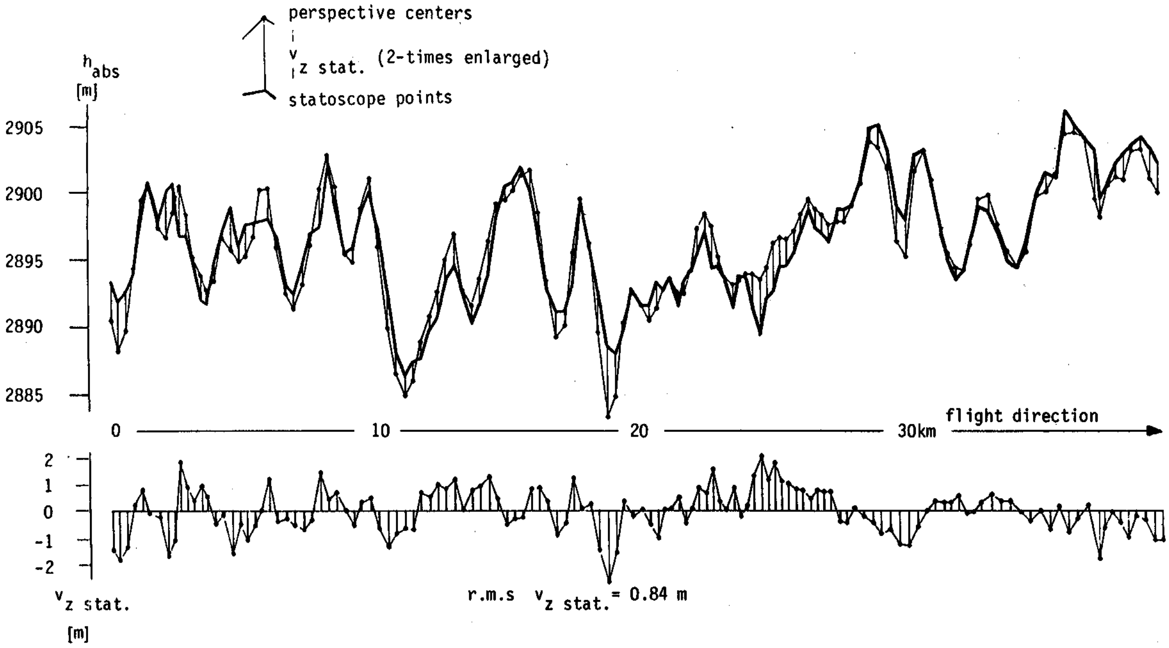

Fig. 14: Test strip A 81 Herrenberg-Oberndorf (1981), Profile of the perspective centers with corrections v_z of the statoscope-measurements (corrected)

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	number of			with statoscope [m]			without statoscope	
control point version	control points	check points	statoscope points	r.m.s. stat.	σ_{oH}	μ_z	μ_z	σ_{oH}
			strip no. 5 (p=60%)					
i ≅ 7.5 b	24	169	33	0.62	0.20	0.34	0.58	0.20
i ≅ 10 b	16	177	33	0.64	0.20	0.36	0.90	0.20
i ≅ 15 b	15	178	33	0.62	0.20	0.40	1.75	0.20
i ≅ 30 b	11	182	33	0.62	0.20	0.43	(12.5)	0.19
			strip no. 6 (p=60%)					
i ≅ 7.5 b	24	173	33	0.81	0.20	0.39	0.57	0.19
i ≅ 10 b	18	179	33	0.85	0.20	0.38	0.96	0.19
i ≅ 15 b	15	182	33	0.81	0.20	0.35	1.38	0.19
i ≅ 30 b	11	186	33	0.81	0.20	0.41	(7.8)	0.19
			strip no. 7 (p=60%)					
i ≅ 7.5 b	24	171	33	0.67	0.19	0.40	0.66	0.19
i ≅ 10 b	18	177	33	0.74	0.19	0.58	0.88	0.19
i ≅ 15 b	15	180	33	0.65	0.19	0.74	1.45	0.19
i ≅ 30 b	11	184	33	0.64	0.19	0.87	(9.2)	0.19
			strip no. 8 (p=60%)					
i ≅ 7.5 b	24	171	32	0.71	0.19	0.45	0.64	0.19
i ≅ 10 b	18	177	32	0.72	0.20	0.59	0.93	0.19
i ≅ 15 b	15	180	32	0.71	0.19	0.62	1.79	0.19
i ≅ 30 b	11	184	32	0.71	0.19	0.60	(5.5)	0.19
			strips no. 5 + 7 (p=80%)					
i ≅ 7.5 b	24	172	66	0.67	0.18	0.29	0.50	0.18
i ≅ 10 b	18	178	66	0.71	0.18	0.38	0.62	0.18
i ≅ 15 b	15	181	66	0.66	0.18	0.46	1.26	0.18
i ≅ 30 b	11	185	66	0.66	0.18	0.54	(12.7)	0.18
			strips no. 6 + 8 (p=80%)					
i ≅ 7.5 b	24	173	65	0.81	0.18	0.34	0.60	0.18
i ≅ 10 b	18	179	65	0.83	0.18	0.46	1.08	0.18
i ≅ 15 b	15	182	65	0.82	0.18	0.42	1.77	0.18
i ≅ 30 b	11	186	65	0.81	0.18	0.42	(8.7)	0.18
			strips no. 5 - 8 (p=90%)					
i ≅ 7.5 b	24	173	131	0.75	0.18	0.30	0.49	0.18
i ≅ 10 b	18	179	131	0.78	0.18	0.40	0.88	0.18
i ≅ 15 b	15	182	131	0.76	0.18	0.41	1.59	0.17
i ≅ 30 b	11	186	131	0.76	0.18	0.42	(13.2)	0.17

control point version	number of control points	number of check points	number of statoscope points	with statoscope r.m.s. stat.	with statoscope σ_{oH}	with statoscope μ_z	[m] without statoscope μ_z	[m] without statoscope σ_{oH}
mean of strips no. 5,6,7 and 8 (p=60%)								
i ≅ 7.5 b	24	171	33	0.71	0.20	0.40	0.61	0.19
i ≅ 10 b	18	177	33	0.74	0.20	0.49	0.92	0.19
i ≅ 15 b	15	180	33	0.70	0.20	0.55	1.60	0.19
i ≅ 30 b	11	184	33	0.70	0.20	0.61	(9.1)	0.19
mean of strips no. 5+7 and 6+8 (p=80%)								
i ≅ 7.5 b	24	172	65	0.74	0.18	0.32	0.55	0.18
i ≅ 10 b	18	178	65	0.77	0.18	0.42	0.88	0.18
i ≅ 15 b	15	181	65	0.74	0.18	0.44	1.54	0.18
i ≅ 30 b	11	185	65	0.74	0.18	0.48	(10.9)	0.18

Table 2: Test strip A 81 Herrenberg-Oberndorf (1981), vertical accuracy results with and without statoscope-measurements

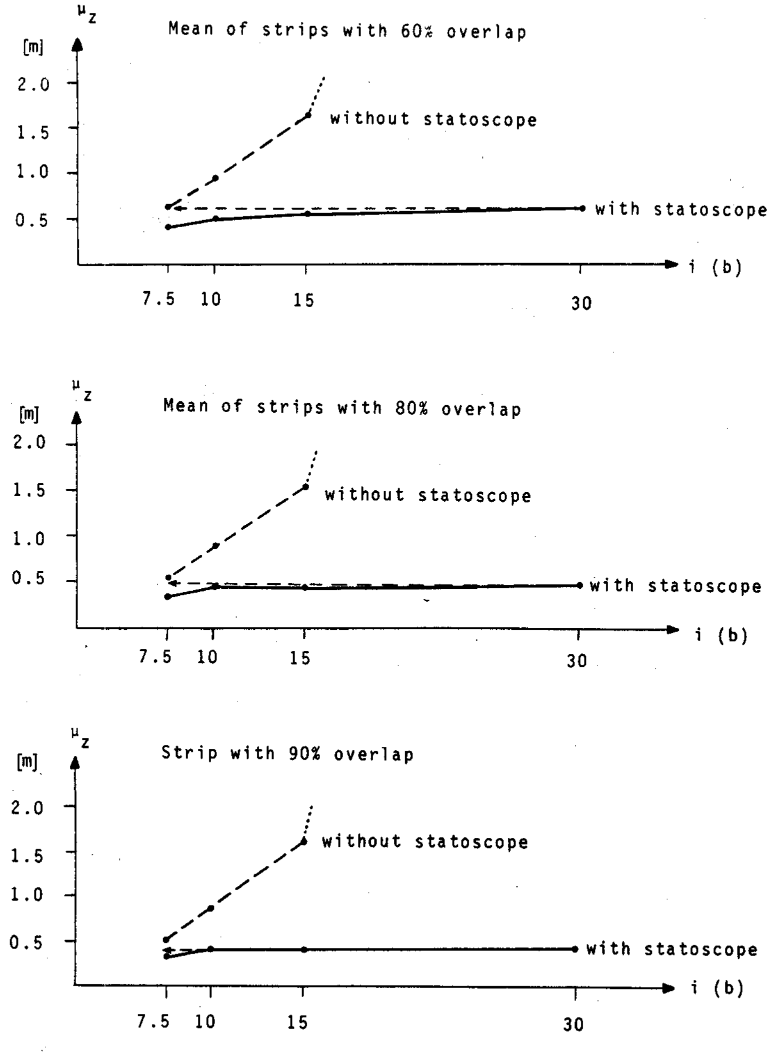

Fig. 16: Test strip A 81 Herrenberg-Oberndorf (1981), vertical accuracy results with and without statoscope-measurements

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Abstract

Previous investigations have shown on the one hand unexpected high accuracy of statoscope data. On the other hand systematic errors in the residuals pointed to possible system errors such as backlash effects.

Therefore, a new test flight "A 81 Herrenberg-Oberndorf" (wide angle, photoscale 1:16,000) was made, with a statoscope of high sensitivity, equipped with an indicator signalling the momentary climbing or descending of the aircraft from which information on the backlash effects was to be derived. The accuracy of the statoscope measurements of about 0.8 - 0.9 m (at 2,900 m absolute flying altitude) was again confirmed, although the anticipated accuracy of 0.5 m could not be reached. After correction of the backlash error the residuals still showed systematic effects, indicating additional system errors.

Nevertheless, simultaneous strip adjustments with the statoscope measurements resulted in vertical accuracies of terrain check points of 0.3 - 0.6 m, for bridging distances of 7 - 30 base lengths, respectively. Thus it is confirmed that the statoscope can be successfully applied also for contouring at map scales of 1:10,000 or 1:5,000.

Neue Versuchsergebnisse von Statoskop-Flügen

Zusammenfassung

Bei früheren Untersuchungen von Statoskopmessungen wurde einerseits eine unerwartet hohe Genauigkeit festgestellt, andererseits ließen größere systematische Anteile in den Restverbesserungen Systemfehler (z.B. Umkehrfehler) vermuten.

Dies war Anlaß zu dem neuen kontrollierten Versuchsflug "A 81 Herrenberg-Oberndorf" (Weitwinkel, Bildmaßstab 1:16 000) mit einem empfindlicheren Statoskop und einer zusätzlichen Anzeige von Steigen und Fallen des Flugzeugs zur Erfassung des Umkehrfehlers. Die Genauigkeit von 0,8 - 0,9 m (bei 2 900 m absoluter Flughöhe) hat sich erneut bestätigt, eine erhoffte Genauigkeitssteigerung in dem Bereich von 0,5 m konnte jedoch nicht erzielt werden. Auch nach Korrektur des Umkehrfehlers zeigten die Restverbesserungen noch systematische Anteile, die auf weitere Systemfehler deuten.

Simultane Streifenausgleichungen mit den Statoskopmessungen ergaben bei Paßpunktabständen von 7 - 30 Basislängen Höhengenauigkeiten der ausgeglichenen Modellpunkte von 0,3 - 0,6 m. Damit ist bestätigt, daß das Statoskop mit Erfolg auch bei Kartenmaßstäben von 1:10 000 und 1:5 000 eingesetzt werden kann.

Photogrammetrische Woche 1981
Institut für Photogrammetrie
Schriftenreihe, Heft 8, 1982

Derniers résultats obtenus par statoscope lors de vols expérimentaux

Résumé

Au cours d'investigations antérieures de mesures effectuées au statoscope, on a constaté d'une part une excellente précision inattendue, d'autre part de grandes erreurs systématiques des corrections résiduelles décelaient des erreurs inhérentes au système telles qu'erreurs de retournement.

Pour cette raison, on a effectué un nouveau vol expérimental "A 81 Herrenberg-Oberndorf" (grand-angulaire, échelle 1:16 000) au moyen d'un statoscope plus sensible avec indication supplémentaire des montées et des descentes de l'avion pour déceler l'erreur de retournement. La précision de 0,8 à 0,9 m (pour une altitude de vol absolue de 2 900 m) s'est à nouveau confirmée, cependant on n'a pas pu obtenir une augmentation de la précision à 0,5 m. Même après la correction de l'erreur de retournement, les corrections résiduelles indiquaient toujours des erreurs systématiques qui signalent d'autres erreurs inhérentes au système.

Les compensations simultanées par bandes réalisées au moyen de mesures au statoscope fournissaient des précisions altimétriques des points compensés de 0,3 à 0,6 m pour un écart entre les points de contrôle de 7 à 30 longueurs de base. Ceci confirme l'emploi efficace du statoscope également pour des échelles de carte de 1:10 000 et 1:5 000.

Nuevos resultados de vuelos fotogramétricos apoyados por el estatoscopio

Resumen

Con motivo de estudios anteriores de mediciones realizadas por estatoscopio se ha observado, por una parte, una exactitud excesiva de los datos obtenidos, pero por otra, componentes sistemáticos mayores en los errores residuales hicieron suponer errores de sistema, p.ej. por inversión del movimiento altimétrico.

Esta observación ha sido la razón para la realización de un nuevo vuelo controlado de ensayo "A 81 Herrenberg-Oberndorf" (objetivo granangular, escala de imagen 1:16 000) con un estatoscopio más sensible y un indicador adicional de la subida o bajada del avion para detectar el error de inversión del movimiento altimétrico. Quedó nuevamente confirmada la exactitud de 0,8 - 0,9 m (con altura absoluta de vuelo 2 900 m), sin embargo, no había sido posible incrementar la exactitud a 0,5 m, lo que se había propuesto. Incluso después de corregido el error de inversión, las correcciones o sea errores residuales ostentaron todavía componentes sistemáticos que insinúan otros errores de sistema.

Con intervalos entre los puntos de apoyo de 7 - 30 bases, las compensaciones simultáneas de fajas resultaron en exactitudes altimétricas de los puntos modelo compensados de 0,3 hasta 0,6 m. Con ello queda comprobado que el estatoscopio puede emplearse con éxito también para trazados de escalas de mapas de 1:10 000 y 1:5 000.

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