THE DIRECT EXPERIMENTAL DETECTION OF THE SYSTEMATIC ERROR OF PRECISE LEVELLING

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ABSTRACT

A method is described for determining one and only one parameter governing the refraction effect of levelling. The central idea is that this parameter is determined not by (temperature) measurements during the observation but by adding one more element in the Least Squares Adjustment of the levelling network.

Furthermore is described an experiment where it was found that this parameter differed significantly from zero and a tentative first value is suggested.

REFERENCES

Remmer, O.: 1977, "The Direct Experimental Detection of the Systematic Refraction Error of Precise Levelling", Geodaetisk Instituts Meddelelse no 52.

DISCUSSION

T.J. Kukkamäki: Dr Remmer mentioned that is is not possible to determine the difference δt. We know that the air temperature is vibrating, but it is possible to determine an average value of δt. You must not use too sensitive thermometers, but thermometers which are integrating for some seconds period. In the morning the observed temperature difference from 0.5 m to 2.5 m height is zero. During daytime it is something like $0^{\circ}.5$ or 1°, and then it is going down toward the evening. We can compute a correction. This correction is not exact for one instrument station, but for 1 km is more representative and for 1000 km still more real. In that way we get average correction, which improve our results.

O. Remmer: I don't think we disagree that much, professor Kukkamäki.

E. Tengström and G. Teleki (eds.), Refractional Influences in Astrometry and Geodesy, 301–303.

Of course, you should have integrations of temperature differences. It is a matter of experience of what you get when you measure things, what are the results when applying these corrections. What we have found is that there is indeed some kind of systematic error which may be attributed to refraction, but maybe there are also other sources. Because if you apply the method I advocate you get hold of all kinds of systematic errors which follow this law, giving proportionality to the square of the distance and direct proportionality to the height difference. Then, of course, you will get every other effect which have this kind of law.

T.J. Kukkamäki: Yes, I agree there are many other sources of errors which hide the refraction effect in regular levelling procedure. But when we exaggerate the refraction effect by using 100 m sightlength, as I described in my paper, we found an effect of 10 mm. The directly observed differences agree with the corrections computed from the temperature observations very well.

O. Remmer: I am relying on older Danish experiences. There has also been some small difference of opinion between the Danish Geodetic Institute and the Finnish on this point. Dr Simonsen was of the opinion that you shouldn't try to find the refraction correction. You should only measure at a time when it was as small as possible. Because he made some experiments where he couldn't find a number, which he could use for these corrections. So the work I have done is more or less a repetition of those. We do not believe so much in applying directly the corrections. We try to estimate them afterwards in some way.

B. Garfinkel: I have only a minor question here. At the distance of 100 m the refraction will contain much noise. And you suggested a distance of 1 km, and there you say that systematic errors are about twice as large as the noise. Now this kind of ratio is still not quite convincing. I suppose if you make it more than 1 km you will get better results.

O. Remmer: Well, this is not a sidelength of 1 km. It is a line composed by ten individual set ups of 100 m distance. It is just a slow accumulation of the systematic error. I mean, the systematic error accumulates by adding linearly, while the random errors accumulate according to the square root of the distance. I am not looking through 1 km of air. I am all the time looking through 50 m of air, and I am doing it ten times. It is only the order of magnitude I have reported.

P.V. Angus-Leppan: I agree with the author that individual measurements of temperatures and temperature gradients don't mean very much. One has to allow them to accumulate before they have any significance. It appears that you are assuming all the systematic errors are due to refraction.

O. Remmer: Yes!

E.G. Anderson: Variations in the temperature with time, particularly during short time intervals, have been mentioned, for instance by professor Kukkamäki. Surely there are also considerable variations in the temperature gradients horizontally along each line of sight. It seems that individual temperature measurements will not be capable of modelling these horizontal variations and we can only approach that problem with some kind of overall, averaged effect. This surely would support Dr Remmer's statistical approach. There seems to have been rather little attention paid to these horizontal variations. Professor Angus-Leppan has shown that this is also a considerable problem, mainly because of the variation of surface material along the line of sight.

O. Remmer: Well, I should like to comment that I have had some experience trying to do as the Finns. And as professor Kukkamäki said, we are more pessimistic in Denmark. We have not been able to get numbers which could be used. I have always had more intuitively than scientifically this feeling. I was measuring the wrong things. I was measuring temperatures which I really could not use.

T.J. Kukkamäki: When we are determining the bending of the light beam, we should measure the gradient on every mm along the line. That would be very good, but in practice not possible. So we measure the gradient only close to the instrument. That is not representative for the whole sightlength of this instrument station. But when we measure a 1000 km long line, we make 10.000 gradient measurements. I think all these measurements will give a rather good average value.

J. Saastamoinen: Maybe the Danish pessimism somehow depends upon the topography of Denmark. What is the height of the highest mountain in Denmark?

O. Remmer: I am not going to speak about high mountains in flat Denmark. Our experiences are based on 20 m height differences.

J. Saastamoinen: The point I wanted to make is the following. Maybe the effect of refraction is quite small even for 20 m height differences. So you are likely not to put too much weight on your results. Finland is also a flat country, but not that flat, and the corrections are much greater.

O. Remmer: I think neither Finland nor Denmark have been noticed for being very hilly. What we have been investigating is a special case. Of course, in a mountainous country - I am sure professor Kukkamäki and I agree - you get a very large error on top of the mountains. That was what professor Kukkamäki said to professor Hradilek. You get the maximum errors at the top of the mountains, of course.

T.J. Kukkamäki: I was just going to say, that after some minutes we will hear something about experiences in the U.S.A., where the gradient is much larger than in these Nordic countries.