First Order Gravity Network of Belgium *

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ملخص:

مابين 1998 و2001 قام كل من المرصد الملكي لبلجيكا و المعهد الجغرافي الوطني البلجيكي بالقيام بعدة حملات لقياس الجاذبية الأرضية لإنجاز شبكة جديدة للجاذبية الأرضية القاعدية البلجيكية (BLGBN98).
هناك 41 نقطة قاعدية. السلم يستلزم ثمانية(8)محطات للجاذبية الأرضية المطلقة.
ميدانيا تم استعمال تسع (9) أجهزة لقياس الجاذبية (LaCoste & Romberg et Scintrex).
تم تقليص المعطيات ضمن تسوية و تعديل مشترك.
تم تحديد مقاييس السلم بالنسبة لكل جهاز.
الخطأ RMS بالنسبة للثقل قدر ب 19µgl.
الخطأ RMS بالنسبة لنقاط الجاذبية رص بين 4 µgl و 10 µgl.
النتائج تبين الإنحرافات لشبكة المرجع السابق المنجزة في سنة 1978.

Résumé :

Entre 1998 et 2001 l'Observatoire Royal de Belgique et le National Géographique
L'institut de Belgique ont exécuté plusieurs campagnes de gravité pour établir un nouveau Réseau de Gravité de Base Belge (BLGBN98).
Il y a 41 points de base. L'échelle est bien contrainte par 8 stations de la gravité absolus.
Neuf gravimètres (LaCoste & Romberg et Scintrex) ont été utilisé sur le champ.
Les données ont été réduites dans un ajustement commun.
Un facteurs de l'échelle ont été déterminés pour chaque instrument.
L'erreur RMS sur le poids de l'unité a atteint 19 µgal.
L'erreur RMS sur les points de gravité aligne entre 4 µgal et 10 µgal.
Les résultats montrent les distorsions d'un réseau de la référence antérieur réalisé en 1978.

Abstract :

Between 1998 and 2001 the Royal Observatory of Belgium and the National Geographic
Institute of Belgium performed several gravity campaigns to establish a new Belgian Gravity Base Network (BLGBN98).
There are 41 base points. The scale is well constrained by 8 absolute gravity stations.
Nine gravimeters (LaCoste & Romberg and Scintrex) have been used on the field.
The data have been reduced in a common adjustment.
A scale factors has been determined for each instrument.
The RMS error on the unit weight reaches 19 µgal.
The RMS error on the gravity points is ranging between 4 µgal and 10 µgal.
The results show the distortions of a previous reference network realized in 1978.

Introduction

The goal was to establish a new fundamental gravity network (Figure 1) with a scale constrained by a maximum of absolute gravity measurements and a precision better than 10 µgal, in order to replace a network observed in 1978 with only one absolute gravity point. This network is a result of a close cooperation between the Royal Observatory of Belgium (ROB) and the National Geographic Institute (NGI) who organised several observation campaigns between 1998 and 2001 (Table1) It benefited from the cooperation of several Belgian and foreign Institute who provided gravimeters (Table 2). We are especially indebted to the "Institut für Physicalische Geodasie, Techmsche Universitat Darmstadt " (IPG-TUD) who provided also an experienced field operator.

We greatly benefited also of the work realised since 1995 by the Royal Observatory of Belgium to establish a dense network of absolute gravity stations.

We used altogether 9 gravimeters on the field, 2 Scintrex and 7 model D or G LaCoste & Romberg. However only 4 instruments (D31, D32, S265 and G336) did effectively observe the complete network. Moreover S265 was sent back to the maker in 2000 and its scale factor was modified.

The network is constrained by 9 absolute gravity stations established by the ROB in Belgium and the neighbouring countries, using a FG5 absolute gravimeter with a nominal precision of 1 µgal. The local gravity gradient has been measured carefully with the S265 instrument. The absolute stations cover the total range of gravity variations i.e. 260mgal.

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For this survey all the points, except the absolute ones, were located outside buildings to keep them permanently accessible. In most of the cases church porches (Figure 2) were chosen for two reasons:

* those places have a high probability to be not altered in the near future;

* generally levelling benchmarks already exist in the vicinity.

The network includes 41 base-stations and their excentric points. The absolute gravity points were included when possible or introduced as excentric points directly connected to the closest station of the network. Altogether some 60 stations were occupied and more than 1,050 ties were measured.

From SE to NW the maximum gravity difference reaches 260 mgal between Arlon and Meer.

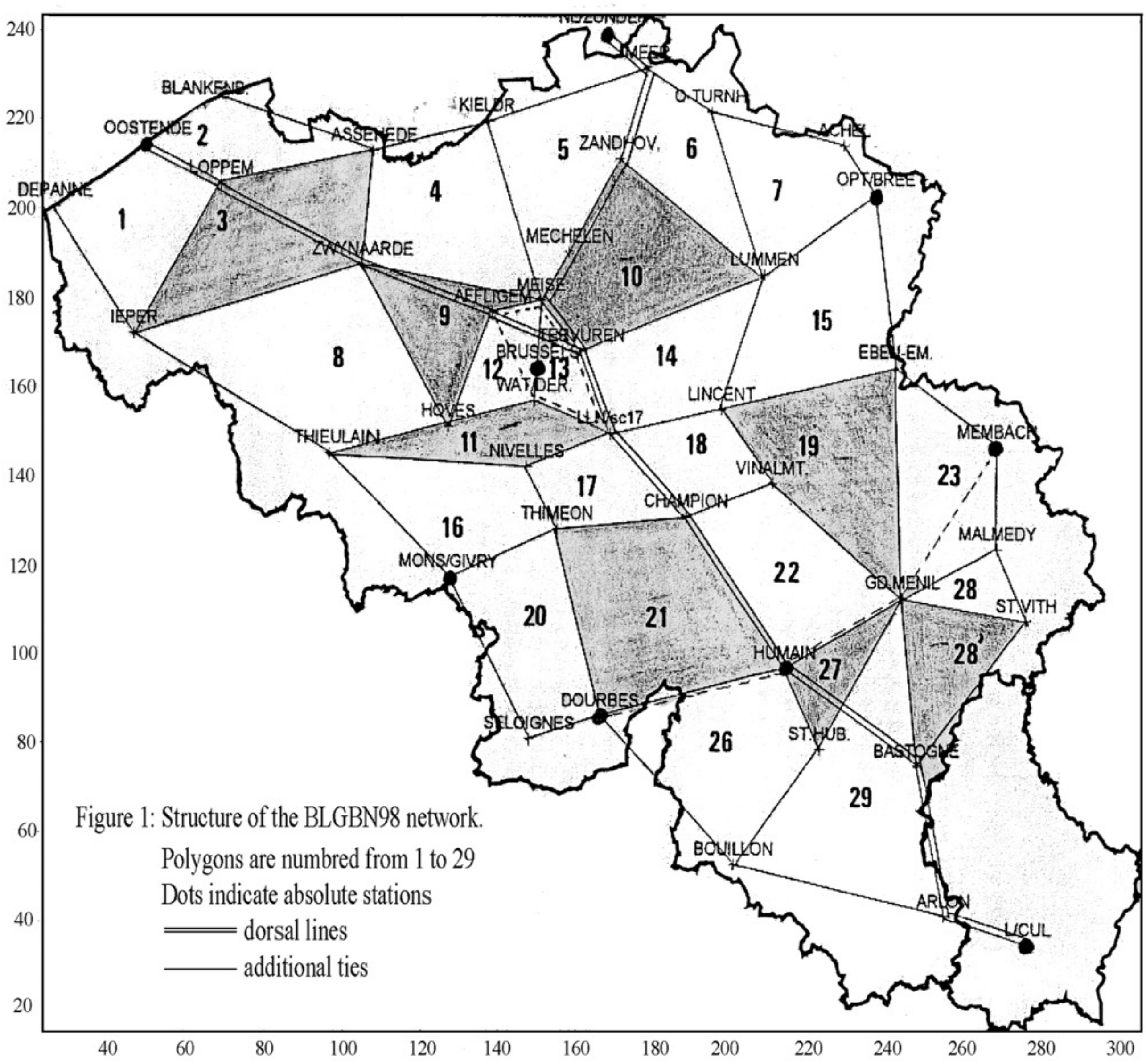


Figure 1: Structure of the BLGBN98 network.

Polygons are numbred from 1 to 29

Dots indicate absolute stations

═══ dorsal lines

——— additional ties

TABLE 1
List of campaigns

ROB & IPG-TUD	NGI
	LCR D31 and D32
3 Days August 98 (S265,G336,G402,G487);	20 days in September and October 99
9 Days May 99 (S265,S342,D38,G258,G336,G402);	
3 Days June 99 (S265,S342,G402);	
4 Days September 99 (G336,G402);	
6 Days October 99 (S265,G336,G402);	
7 Days July 2001 (S265,G336,G487).	

total 162 "Gravimeter Days"

TABLE 2
List of Instruments:

Scintrex S265, LCR G402, LCR G336 Royal Observatory of Belgium (ROB)
LCR G487 Metrological Service of Belgium
LCR D31 Université catholique de Louvain et Université de Liége
LCR D32 National Geographical Institut (NGI)
Scintrex S342 Université de La Rochelle
LCR D38, G268 Institut für Physicalische Geodäsie, Technische Universität Darmstadt

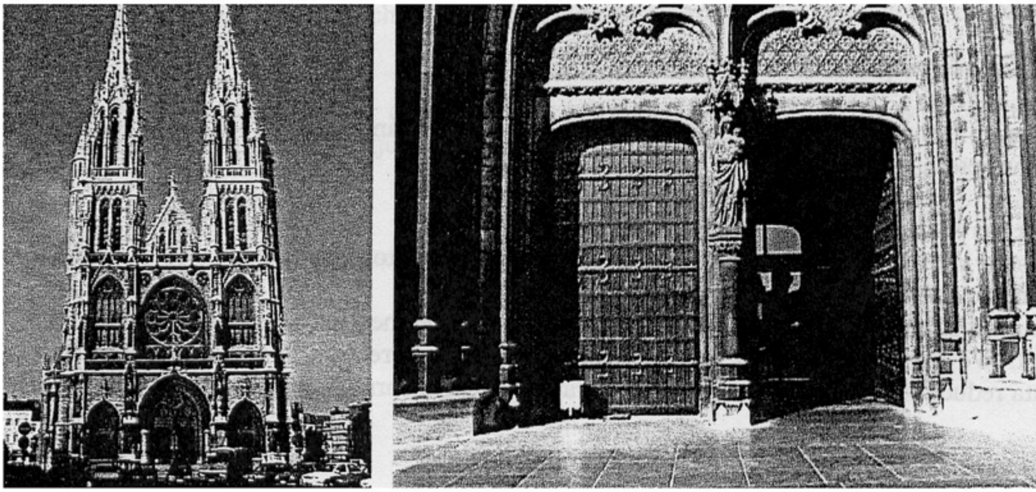
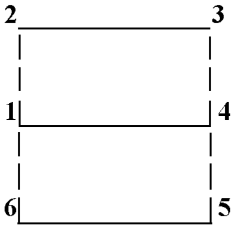


Figure 2: Gravity observation at Oostende station

2. Structure of the network (Figure 1)

To ensure the independence of the ties inside a loop the optimal solution should be to link each station with its direct neighbours in a sequence 1-2-1. Of course with 41 stations it is a very heavy task and we had not enough manpower to follow this schedule.

- The base network is subdivided in 27 polygons with 4 stations each. Two polygons are observed on the same day in a sequence 1-2-3-4-1-6-5-4 with two closures on the common side. The gravity differences are thus correlated inside of the loops.



A standard working day consists thus in measuring 8 points and requires less than 12 hours.The optimal solution 1-2-1-4-1-6-1, 3-2-3-4-3, 5-4-5-6-5 should require 17 measurements.

In any case a partial decorrelation is obtained when observing adjacent polygons.

- To strengthen the structure we observed several dorsal lines starting from Brussels to the North West, the North and the South East in a sequence 1-2-3-4-3-2-1 (====== on figure 1).

Each of them was observed at least two times.

To limit the observational task we also decided to omit 8 polygons (shaded area) which connect stations that are already observed in other polygons. The effect of this decision was that a few stations on the border of the network were observed only once and we shall see that after adjustment they exhibit a larger RMS error.

The NGI observed the complete network in September-October 1999 with 2 gravimeters. The stations located to the East of the line Meer-Arlon were occupied in May 1999 by ROB and IPG-TUD with 6 instruments. In October 1999 ROB completed the network with only 3 gravimeters.

3. Measuring techniques

The measuring technique was slightly different for the Scintrex and the LaCoste & Romberg (LCR) gravimeters.

3.1 The Scintrex instruments

We use a 60s integration with continuous tilt adjustment and automatic rejection of bad data (Scintrex manual, 1992; Ducarme & Somerhausen, 1997).

The instrument is installed on the site 10 minutes before starting measurements for temperature adjustment. We perform at least 5 measurements. The tidal correction is applied during the offline data reduction (§4.1). The residual temperature effect is corrected online by the internal software.

3.2 The LCR instruments

We do not perform optical readings as the resolution is not sufficient for our purpose.

For all gravimeters we have access to an analogic signal in mV or Hz proportional to the difference between the real beam position and the reading line (van Ruymbeke, 1991; van Ruymbeke & al.,1995). This signal is linear on a larger than 1 mgal range. We do not try to zero exactly the gravimeter but we always use full divisions on the dial and correct for the residual signal. It allows to reach a one microgal resolution even with the G meters (Ducarme & al., 1976).

- After the levelling, we do a coarse micrometer adjustment on the zero within one dial unit (10 μgal) for model G or one counter unit (10 μgal) for model D.
- We perform a 100 μGal displacement on each side of this preliminary position to determine the conversion factor mV or Hz to micrometer units.
- We do a minimum of 3 measurements to within 10 μgal of the zero and measure the residual signal. This complete procedure requires up to 15 minutes after unclamping.

Aims of this procedure

-This procedure allows a 10 minutes stabilisation of the instrument before starting the precise measurements;

-We determine for each station the conversion factor from mV or Hz to counter units;

-The successive readings are used to check the stability of the instrument and to detect anomalous measurements, reject them and make some additional readings if required.

To speed up the procedure it is possible to perform only a series of 4 measurements in a sequence: zero, +100, -100, zero. Then the reduction should be performed by least square adjustment (§4.1.2).

4. Data reduction

The reduction of the data is performed in different steps

- First step: for each loop and each instrument we compute, at each station, the mean value converted to physical units and corrected of the tidal effects.

- Second step: for each instrument we calculate the drift for the different possible closures of the loop to compute the gravity difference for each tie. We select semi-automatically the independent ties of each loop by choosing the best closure. Anomalous ties can be rejected at that level.

-Third step: All selected ties for one or several instruments are collected in a file with the format required by the network adjustment programs.

4.1 Mean corrected value

The tidal correction is computed for the mean epoch, as the tidal changes are quite linear on a few tens of minutes. What is more important is the use of regional tidal parameters as they can differ from a constant tidal factor by more than 10%. For a loop of 6 hours it means differences of more than 10 μgal. We also use the same coordinates for all the stations belonging to the same loop.

For Scintrex instruments the mean value of the different readings is directly computed. The discrepancy between each reading and this mean is evaluated to detect outliers.

The reduction of the LaCoste & Romberg gravimeters is possible according to different schemes.

4.1.1 standard procedure (Tables 3a and 4)

For each displacement we compute the exact value by subtracting the residual signal multiplied by the conversion factor derived from the large displacements.

Table 3
Comparison of standard and simplified procedures
Gravimeter GD-032, Maker's calibration factor: 1.06073

a) standard procedure
Conversion factor mV to micrometer unit: 0.07120
Mean Corrected Micrometer value: 125685.18
Mean value converted in µgal: 153411.33
Mean time for tidal correction: 9h 06m UT
Tidal correction (µgal): +21.06
Tidefree mean value: 153390.27

EPOCH	Raw Micrometer	SIGNAL (mV)	Corrected. Micrometer	RESIDUE (micom. Unit)
1999 10 01 09 03	125685	0.	125685.00	-.18*
1999 10 01 09 04	125785	1409.	125684.68	-.50+
1999 10 01 09 05	125585	-1400.	125684.68	-.50+
1999 10 01 09 05	125685	0.	125685.00	-.18
1999 10 01 09 06	125695	139.	125685.10	-.07
1999 10 01 09 06	125675	-139.	125684.90	-.21
1999 10 01 09 07	125685	-10.	125685.71	.53
standard deviation	0.37 micrometer unit			

+ calibration displacement not included in the mean
* eliminated reading

b) linear regression
REGRESSION ON 7 POINTS: CM = A + B *(RM - 125686)
A= 0.01 B= 0.071204
±.15 ±.000192
STANDARD DEVIATION S= .38281991

Mean Corrected Micrometer value: 125685.01
Maker's calibration factor: 1.2206
Mean value converted in µgal: 153411.12
Mean time for tidal correction: 9h 05m UT
Tidal correction (µgal): +21.06
Tidefree mean value: 153390.06

EPOCH	Raw Micrometer	SIGNAL (mV)	Corrected Micrometer	RESIDUE (microm. Unit)
1999 10 01 09 03	125685	0.	125685.00	-.01
1999 10 01 09 04	125785	1409.	125684.67	-.34
1999 10 01 09 05	125585	-1400.	125684.69	-.32
1999 10 01 09 05	125685	0.	125685.00	-.01
1999 10 01 09 06	125695	139.	125685.10	.09
1999 10 01 09 06	125675	-139.	125684.90	-.11
1999 10 01 09 07	125685	-10.	125685.71	.70
standard deviation	0.35 micrometer unit			

Table 4
Data reduction using the standard procedure
Gravimeter GR-487, Maker's calibration factor: 1.0255

Conversion factor mV to micrometer unit: 0.0891
Mean Corrected Micrometer value: 4612838.10
Mean value converted in µgal: 4730465.47
Tidal correction (µgal): -34.48
Tidefree mean value: 4730499.94

EPOCH	Raw Microm.	SIGNAL (mV)	Corrected Micrometer	RESIDUE (dial units)
2001 07 03 07 02	4612820	-55.	4612824.90	-13.20*
2001 07 03 07 04	4612920	1005.	4612830.47	-7.63+
2001 07 03 07 06	4612720	-1240.	4612830.47	-7.63+
2001 07 03 07 08	4612830	-78.	4612836.95	-1.15
2001 07 03 07 10	4612840	22.	4612838.04	-.06
2001 07 03 07 13	4612830	-100.	4612838.91	.81
2001 07 03 07 15	4612840	17.	4612838.49	.39
standard deviation	0.84 dial unit			

+ calibration displacement
* eliminated reading

These large excursions are not taken into account for the computation of the mean value as well as the preliminary reading which is only a coarse adjustment.

4.1.2 least square adjustment (Table 3b)

It is also possible to perform directly a linear regression between the residual signal and the different values of the micrometer. The slope gives the sensitivity and the independent term the crossing of the zero i.e. the true value of ten micrometer.

Comparison of Tables 3a and 3b shows that the two procedures give the same result for the individual readings. The difference for the mean value is due to the different choice of the included readings. However they generally agree within the associated standard deviation. A larger disagreement should be interpreted as a sign of instability.

The simplified procedure (4 readings only) gives excellent results if the gravimeter is not drifting after unclamping as in the previous example. However for some instruments the first value can be quite different from the following ones (Table 4) and should indeed be suppressed and then 3 readings will not insure the required precision. It's why we normally always use at least 3 readings after the 2 calibration displacements and normally discard the preliminary reading.

Table 5
Computation of the different closures
Connection between station Givry (7041) and absolute point in Mons (7000)
Gravimeter Scintrex 265

STATION	EPOCH	RAW VALUE (µgal)	DRIFT CORR. VALUE (µgal)	gravity diff. (µgal)
closure 1 on station 7000	:drift/day =	-128.8		
7000	2001 07 20 08 00	5325738.75	5325738.75	
				-7902.15
7041	2001 07 20 08 59	5317831.29	5317836.60	
				7902.15
7000	2001 07 20 10 02	5325727.85	5325738.75	
+				
*closure 2 on station 7000	:drift/day =	-158.2		
7000	2001 07 20 08 00	5325738.75	5325738.75	
				-7900.93
7041	2001 0720 08 59	5317831.29	5317837.82	
				7903.43
7000	2001 07 20 10 02	5325727.85	5325741.25	
				-7903.38
7041	2001 07 20 10 53	5317818.85	5317837.86	
				7900.89
7000	2001 07 20 11 47	5325713.76	5325738.75	
+				
closure 3 on station 7041	:drift/day =	-157.6		
7041	2001 07 20 08 59	5317831.29	5317831.29	
				7903.40
7000	2001 07 20 10 02	5325727.85	5325734.69	
				-7903.40
7041	2001 07 20 10 53	5317818.85	5317831.29	
+				
closure 4 on station 7000	:drift/day =	-192.3		
7000	2001 07 20 10 02	5325727.85	5325727.85	
				-7902.17
7041	2001 07 20 10 53	5317818.85	5317825.68	
				7902.17
7000	2001 07 20 11 47	5325713.76	5325727.85	
+				

* selected closure

4.2 Drift computation and selection of the ties

For each loop the program identifies all possible closures for computation of a linear instrumental drift (Table 5).

For each loop the best independent closures are manually selected. In the case of reiterated closures on a same point it is possible to select successive closures or the global one as in the example of Table 5. The choice will depend on the linearity of the drift on the complete observation span. If the global solution is rejected, care should be taken at that level not to keep duplicated ties in two independent closures.

4.3 Preparation of the input files for least square adjustment

We are using two adjustment softwares, ADJNODE (Ph.Lambot) and ADJG (Jiang, 1988), which require different input format. We had to write the program FORMADJ to rewrite the ties in the correct format. This program is also able to mix and sort ties of different instruments as well as to make statistics on the ties between each pair of stations.

5. Network adjustment

The adjustment of the network is first performed for each instrument independently to check the internal coherency, before computing a global compensation including the determination of individual scale factors for the gravimeters, the scale of the network being controlled through several absolute points with large gravity differences.

5.1 Individual adjustments:

For each gravimeter we perform an adjustment of the gravity values with reference to a fixed point to detect the gross errors in the observations. For this purpose we use the software " ADJNODE". Besides gravity differences with respect to the fixed point and the associated RMS errors this least square adjustment computes the residual for each tie. We eliminate the ties with residues larger than 3 times the RMS error on the unit weight. In table 6 we give the RMS error associated with each gravimeter. As the program is normally used for the adjustment of the nodes in a network observed in a way similar to a levelling network, the ties are supposed to be independent. As already noticed our ties are correlated inside of a loop and it reduces the estimated errors in the least square adjustment. This correlation will largely disappear in the global adjustment due to the mixture of several instrument. The estimated errors on each instrument will increase accordingly.

5.2 Global adjustment:

We perform a final adjustment with all the instruments constrained by the absolute gravity values. For that purpose we adapted the software "ADJG" (Jiang & al., 1988; Ziang, 1999). The weight of the absolute gravity values can be adjusted according to their estimated accuracy. For each gravimeter we can compute a polynomial adjustment of its scale factor. For LCR D meters we can, of course, compute only a constant scale factor as the readings depend from the reset adjustments. Moreover the ADJG software allows also the determination of cyclic micrometer errors but we did not use this option.

The standard output provides for each station, including the absolute ones, the adjusted gravity value with its RMS error. The discrepancy between the adjusted and observed value of the gravity points should not exceed the associated RMS error.

For each gravimeter we get also the RMS error on the residuals for each tie giving an estimation of the precision of the instrument. The sum of the residuals indicates if any bias is present for a given instrument.

6. Final Adjustment

Our final adjustments incorporate more than 1050 ties observed with the 9 gravimeters. It was constrained by up to 9 absolute gravity values.

Each tie has a unit weight and the absolute gravity values an adjustable weight P, normally equal to 4. This choice is justified a posteriori by the fact that the RMS error on the absolute points is close to 5 µgal compared to 20 µgal for a single tie.

For each gravimeter we computed a single scale factor. Polynomial adjustment of the scale did not provide results statistically better.

To reduce the internal errors we rejected ties with a residue higher than three times the observed standard deviation on the unit weight. We suppressed so about 1% of the ties. The standard deviation was reduced from 25 µgal to 20 µgal, without any significant change in the solution.

There are two degrees of freedom in the solution i.e. the number of absolute gravity points included and their weights. We thus have to select the best solution taking into account the following criteria.

- The sum of the residues on the links after adjustment should be as close as possible to zero.

If not, there exists a strong distorsion in the solution.

- The RMS errors on the computed gravity values should be minimum.
- At the absolute gravity points, the difference between the computed value G and the nominal value g should be less than the associated RMS error M.

7. Selected solution

The first criterion is always satisfied. However there is a conflict between the absolute station of Humain (HUM) in the South-East of Belgium and the neighbouring absolute stations of Dourbes (DOU), Luxembourg (LUA) and Membach (MEM). Moreover the tie between Arlon and Luxembourg is still weak.

- The solution including the 9 absolute stations with an equal weight (Table 7) is violating the criterion concerning the absolute stations with a difference of –20 µgal between the computed G and the a priori g values at Humain and large residues with opposite sign on the three conflicting stations. However this solution gives the lowest RMS errors on the stations in eastern Belgium.
- The solution excluding Humain (Table 8) fulfils the criterion on the absolute stations but with slightly higher RMS errors in the Eastern part of the network. At Humain the difference between the adjusted gravity G and the observed gravity g reaches 29 µgal, clearly indicating a systematic error.

From SE to NW the difference between the two solutions reaches 11 µgal in Arlon, decreases to 5 µgal in Champion, 1 µgal in Brussels and changes its sign to –2 µgal in Meer. It means that most of the network is constrained to better than 5 µgal. The absolute value in Humain is certainly questionable and should be rejected from the adjustment. This conviction is corroborated by the fact that this station had also to be eliminated by ROB from the project "Soulèvement de l'Ardenne" for inconsistent reiteration results. We selected thus the second solution with only 8 absolute gravity values.

Table 6
INDIVIDUAL ERROR ESTIMATION

GRAV	RMS err (µ gal)	GRAV	RMS err (µgal)	GRAV	RM err (µgal)
GD - 31	: 16.4	GD - 32	: 10.1	GD - 38	14.4
GR - 258	: 20.7	SC - 265*	: 9.9	GR - 336	11.2
SC - 342	: 13.5	GR - 402	13.7	GR - 487	17.9

* before revision in 2000

TABLE 7: **CORRECTIONS TO THE ABSOLUTE POINTS**
in units of mgal

No	POINT	Sn	g observed	G adjusted	G-g	RMS error
1	BRU	105.00	981128.877	981128.877	.000	.005
2	LUA	151.10	980960.407	980960.415	.008	.007
3	NLZ	232.20	981196.849	981196.853	.004	.007
4	BRE	396.01	981149.022	981149.016	-.007	.006
5	MEM	483.71	981046.730	981046.737	.007	.006
6	DOU	567.00	981018.151	981018.159	.008	.006
7	**HUM**	**690.01**	**981002.122**	**981002.102**	**-.020**	**.005**
8	MNS	700.00	981082.876	981082.874	-.002	.006
9	OST	840.01	981173.303	981173.304	.001	.007

TABLE 8: **CORRECTIONS TO THE ABSOLUTE POINTS**
Station Humain (HUM) eliminated
in units of mgal

No	POINT	Sn	g observed	G adjusted	G-g	RMS error
1	BRU	105.00	981128.877	981128.876	-.001	.005
2	LUA	151.10	980960.407	980960.409	.001	.008
3	NLZ	232.20	981196.849	981196.855	.006	.007
4	BRE	396.01	981149.022	981149.015	-.007	.006
5	MEM	483.71	981046.730	981046.732	.002	.006
6	DOU	567.00	981018.151	981018.152	.001	.006
7	MNS	700.00	981082.876	981082.872	-.004	.007
8	OST	840.01	981173.303	981173.305	.002	.007

8. Repartition of errors on the gravity values

The errors on the gravity values are spatially correlated and ranging between 4 µgal and 10 µgal. On Figure 3 it is clearly seen that the repartition is influenced by the dorsal lines and the absolute points. It should be noted also that the points to the SW of the main dorsal line Arlon-Meer have been occupied by only 6 gravimeters.

Outside the province of Luxembourg the larger errors on the edges of the network correspond to stations, which have been occupied only once according to our schedule.

In the province of Luxembourg we notice a broad zone with 8 µgal errors although Arlon and Bastogne are on the SE dorsal line. To strengthen the solution in the South-Eastern part of Belgium we should improve the tie with Luxembourg absolute point and probably install an absolute point in Arlon where we reach the lowest gravity value of the net.

9. Normalisation and internal errors for the gravimeters

- The normalisation factors computed for each gravimeter are given in Table 9. It should be noted that these factors are insensitive to the choice of the absolute points and remained constant in all the solutions.

The Scintrex gravimeter belonging to ROB has two different factors. Prior to a revision (SC265) it is affected by a calibration error of 0.1%. The new factor given by the manufacturer after revision (SC266) seems correct.

Several gravimeters require a normalisation factor:
D38 (.03%), G336 (.05%), SC342 and G402 (.08%)
Other instruments do not require adjustment:
D31,D32,G258,G487

- The RMS errors on the unit weight are very different (Table 9), ranging from 12.8 µgal to 16.4 µgal for the Scintrex instruments and 15.7 µgal to 26.4 µgal for the LaCoste ones. Comparing with table 6 it should be noted that the errors, as expected, are larger in the global adjustment but that the hierarchy of the instrument is confirmed.

The D32 is exceptional. Not only it has the lowest internal error among the LaCoste gravimeters used but also no tie of this instrument had to be rejected.

10. Comparison with the previous network

In 1978 a base gravimetric network of 27 stations had been measured using 6 LaCoste & Romberg G and D gravity meters (Poitevin & Ducarme, 1980). It was referred to the absolute station measured at ROB in 1976 by the "Istituto de Metrologia G. Colonetti". No external constraint was available for the scale determination and all instruments were scaled on the LCR008 which was the best instrument (Poitevin, 1980).

Only a few stations are common to both networks. On figure 4 we give the difference expressed in microgal between this old network and the new one.

Besides an offset of- 12 µgal due to the revision of the Brussels absolute value we clearly see an overall tilt from NW to SE of more than 100 µgal. As this direction corresponds to the main gravity gradient it could be explained by a systematic scale error of 0.04%, which is not unlikely for a LaCoste & Romberg instrument.

TABLE 9
THE NORMALISATION FACTORS and INTERNAL ERRORS

GRAV.	NORM. FACT.	N TIES	RMS error (µgal)
GD- 31 :	1.0002721 ±.0000780	103	21.8
GD- 32 :	1.0001578 ±.0000969	108	15.7
GD- 38 :	0.9997272 ±.0000849	63	22.0
GR-258 :	1.0001481 ±.0000870	47	26.4
SC-265 :	0.9990790 ±.0000677	213	12.8
SC-266*:	1.0005379 ±.0001969	43	(8.9)
GR-336 :	1.0004703 ±.0000727	179	18.3
SC-342 :	1.0008077 ±.0000763	97	16.4
GR-402 :	1.0008177 ±.0000704	153	19.9
GR-487 :	1.0001064 ±.0001012	55	25.2
GLOBAL		**1061**	**18.7**

*after revision in 2000 the SC265 was renamed SC266 for the partial survey performed in 2001

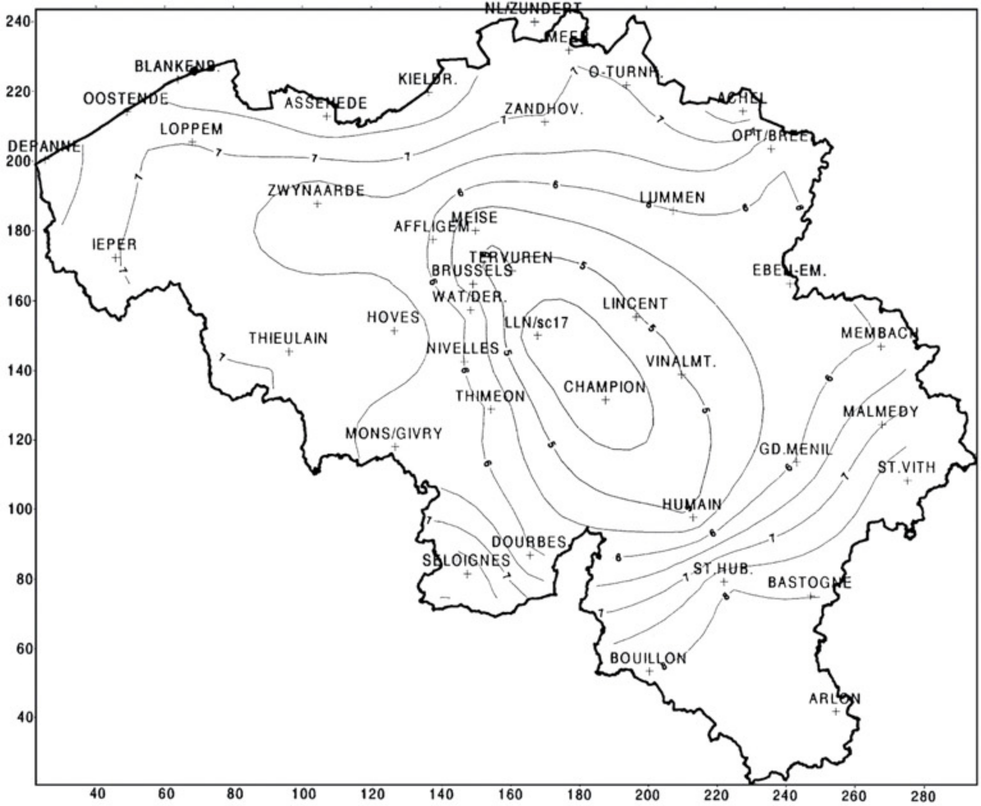


Figure 3: Repartition of the RMS error on the gravity values expressed in µgal

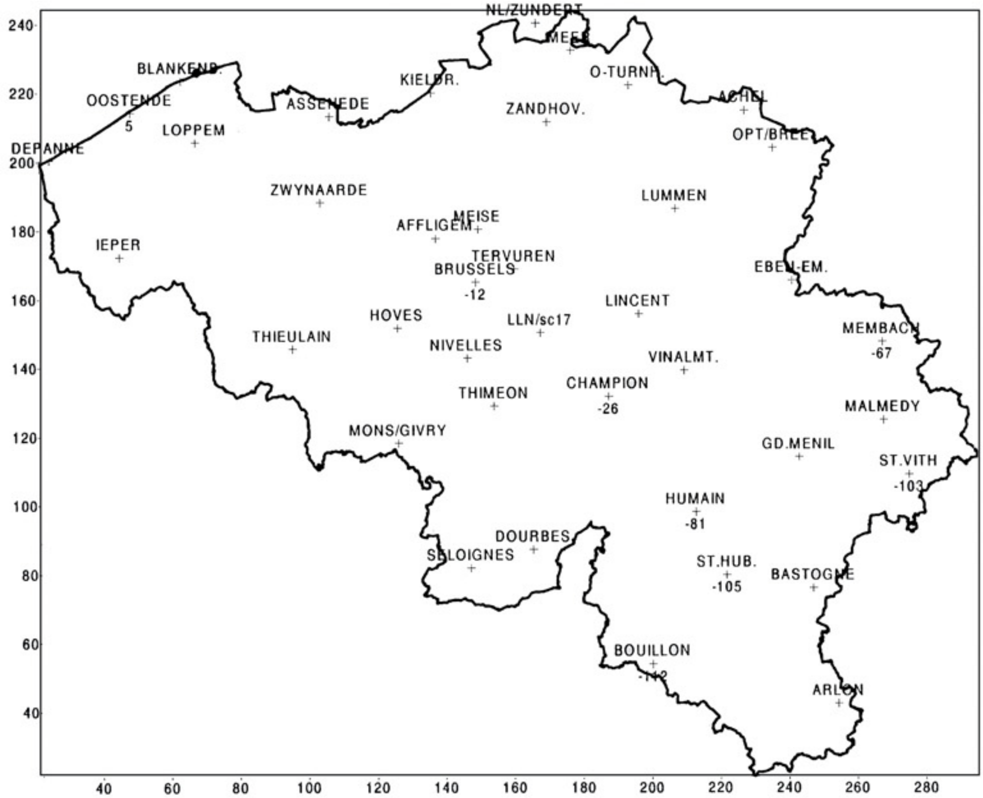


Figure 4: Difference in µgal between BLGBN98 and the previous 1978 network

11. Conclusions

- Around 1050 ties performed with 9 different instruments link the 41 base stations and their excentric points.
- The RMS error on the unit weight is 19 µgal.
- The RMS errors on the gravity values are comprised between 4 µgal and 10 µgal.
- The solution is perfectly stable in most of the country except in the province of Luxembourg in the SE, where the maximum difference between two extreme solutions reaches 10 µgal. It is due to an abnormal value in one of the nine absolute stations, conflicting with the surrounding ones. This anomalous station has clearly to be rejected.
- The new gravity base network of Belgium is well constrained by the 8 remaining absolute gravity stations.
- We have now corrected the global distorsion of the previous network are thus able to perfectly unify all the local networks observed in Belgium since more than 10 years.

We recommend to improve the stability of the results in the SE corner of the network. For that purpose we are planning:
- To install in this area, i.e. in Arlon, an additional absolute point m a more stable station.
- To improve the relative gravity ties with the absolute station in Luxembourg City;

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