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B U L L E T I N D ' I N F O R M A T I O N

Mars 1967

N°18

T A B L E des M A T I E R E S

Bull. n°18

- I -

GRAVITY MEASUREMENTS AT SEA

GRAVIMETRICAL TEST-WORK

- II -

Note : Bull. Inf. n°17, p.5, - Dans la liste des Rapports Nationaux, le rapport de Finlande avait été omis.

AN ANALYSIS OF THE ERRORS IN GRAVITY MEASUREMENTS AT SEA

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Introduction

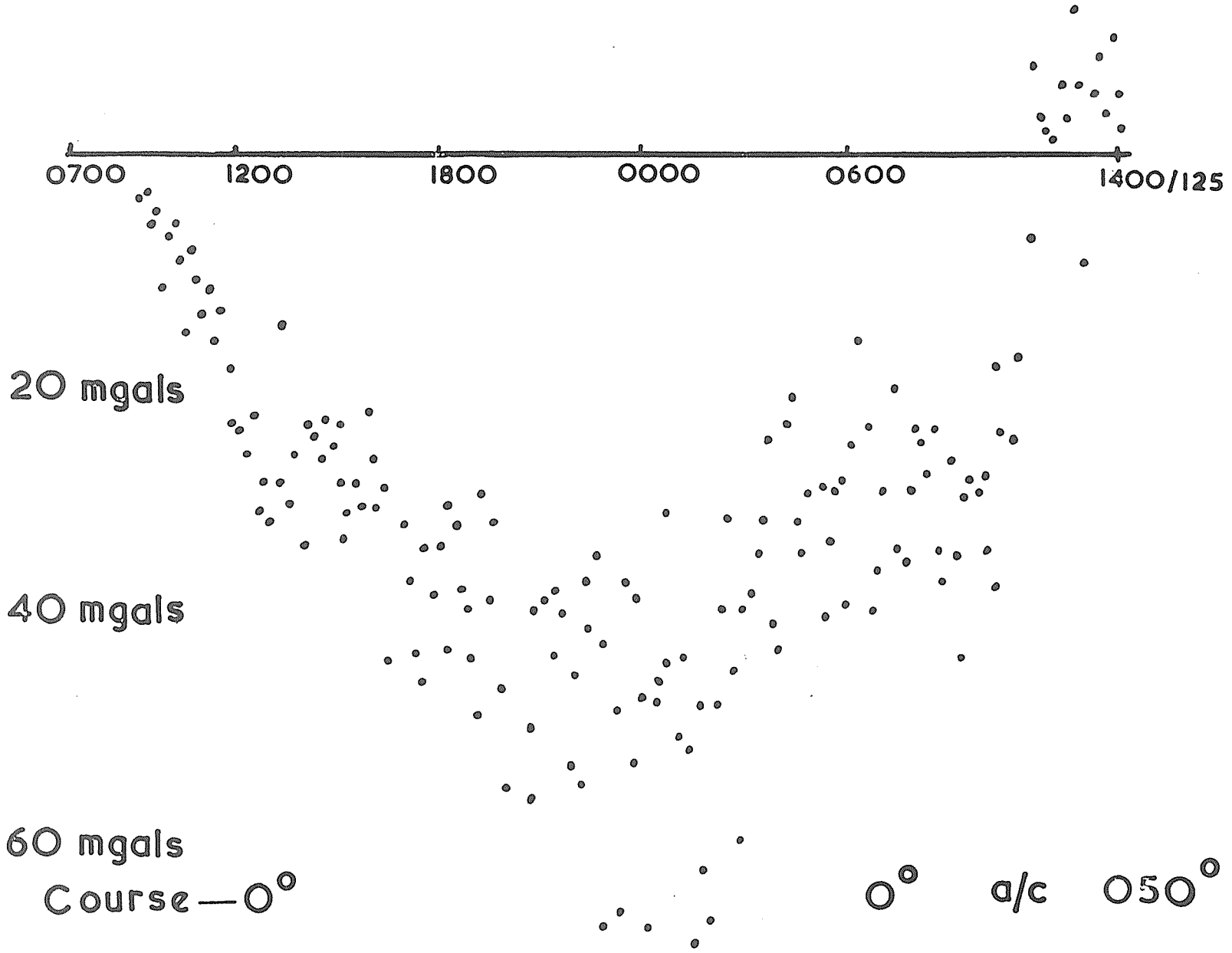
During the past five years several workers have been concerned with the correction for, or elimination of, cross coupling and off-levelling errors in gravity measurements at sea. Talwani (1966) has demonstrated some success by comparing the output from a cross coupling computer with the disturbed gravity trace simultaneously observed and obtaining a corrected smooth gravity profile. Likewise, the cross coupling computer built at Cambridge University (Haworth, 1967) has been used for the correction of errors apparent in gravity measurements made by Cambridge and also Bedford Institute of Oceanography. Despite the apparent success of this correction method, no absolute verification of the magnitude of cross coupling had been provided, and the magnitude of any residual errors had not been investigated.

During the period April to June 1967, the Department of Geodesy and Geophysics, Cambridge University and the Hydrographic Department were cooperating on a cruise aboard H.M.S. HECATE to investigate absolutely the cross coupling errors encountered aboard HECLA class survey ships. HECATE was equipped with two Askania sea gravimeters (fig.1.) mounted facing opposite directions, one forward of the other, but as close to each other as possible : In tandem so to speak. With such an arrangement the cross coupling errors encountered by each meter are presumed to be equal in magnitude but opposite in sign. The mean output of the two gravimeters gives the true gravity profile and the meter reading difference is twice the cross coupling error. Hence in addition to providing an absolute check on the magmitude of the errors, the method provides a control for checking the efficiency of an independent system for computing the cross coupling errors.

Analysis and results

Meter difference profiles have been prepared for passage Plymouth-Gibraltar-Monaco-Plymouth and these indicate the presence of errors up to 35 mgals under normal survey conditions as encountered during the period dealt with in fig. 2.

fig. 2 Meter Difference Profile



In order to present a complete set of results in the time available, a section of the total passage was chosen for closer examination. The section used was the crossing of the Gulf of Lions on April 24th (fig. 3.). A storm developed on the shores of the Gulf and the sea from it was directed at our port quarter so that the ship was rolling rather than pitching. The worst sea conditions encountered at this time was a 15 ft. sea with a period of 8 seconds being driven by a 30 knot wind. Under such conditions there should have been no misbehaviour of the gyro platform as seems evident in heavy seas. The errors present were in the range 5 to 10 mgals (fig. 4.), and hence this also provides a reasonably critical test of the Cambridge cross coupling computer

The data on which this report is based are shown in fig. 5. Shown are the two gravimeter traces laterally displaced to allow comparison between the traces. It was also necessary to displace one trace along the time axis by approximately half a minute in order that perturbations common to both traces should occur at the same time. This implies a difference in the time constants (delays) of the two meters. The third solid line is the output of the cross coupling computer, the calibration of which was one of the objectives of the trial. The broken line is the difference between the two meter readings and the scale of this is shown on the left in terms of the meter difference i.e. twice the amount of cross coupling. The computer output trace is plotted on the same scale using a theoretical calibration factor. The discrepancy indicates the error in the calibration factor and demonstrates the drift of the computer.

If the two gravimeters profiles have the same irregularities superimposed (by irregularities I mean variations in the gravimeter output with periods of 1 to 10 minutes) it seems probable that these irregularities if of opposite sign are caused by cross coupling in which case the computer ought to account entirely for the difference between the two meter readings. However if the irregularities are not the same the proposition that the cross coupling error is half the difference between the two meter readings is incorrect and the reliability of any mean profile is reduced.

On passage across the Gulf of Lions, long period variations of an hour or more caused by a physical change in gravity are to be seen in both traces. Of slightly shorter period, again in both traces, we find variations of opposite polarity such as that between 0930 and 1020. This implies that cross coupling errors exist with a period of an hour and this is very important since upon examining either trace separately we would have presumed any such excursion to be a physical change in gravity and not the error which it is.

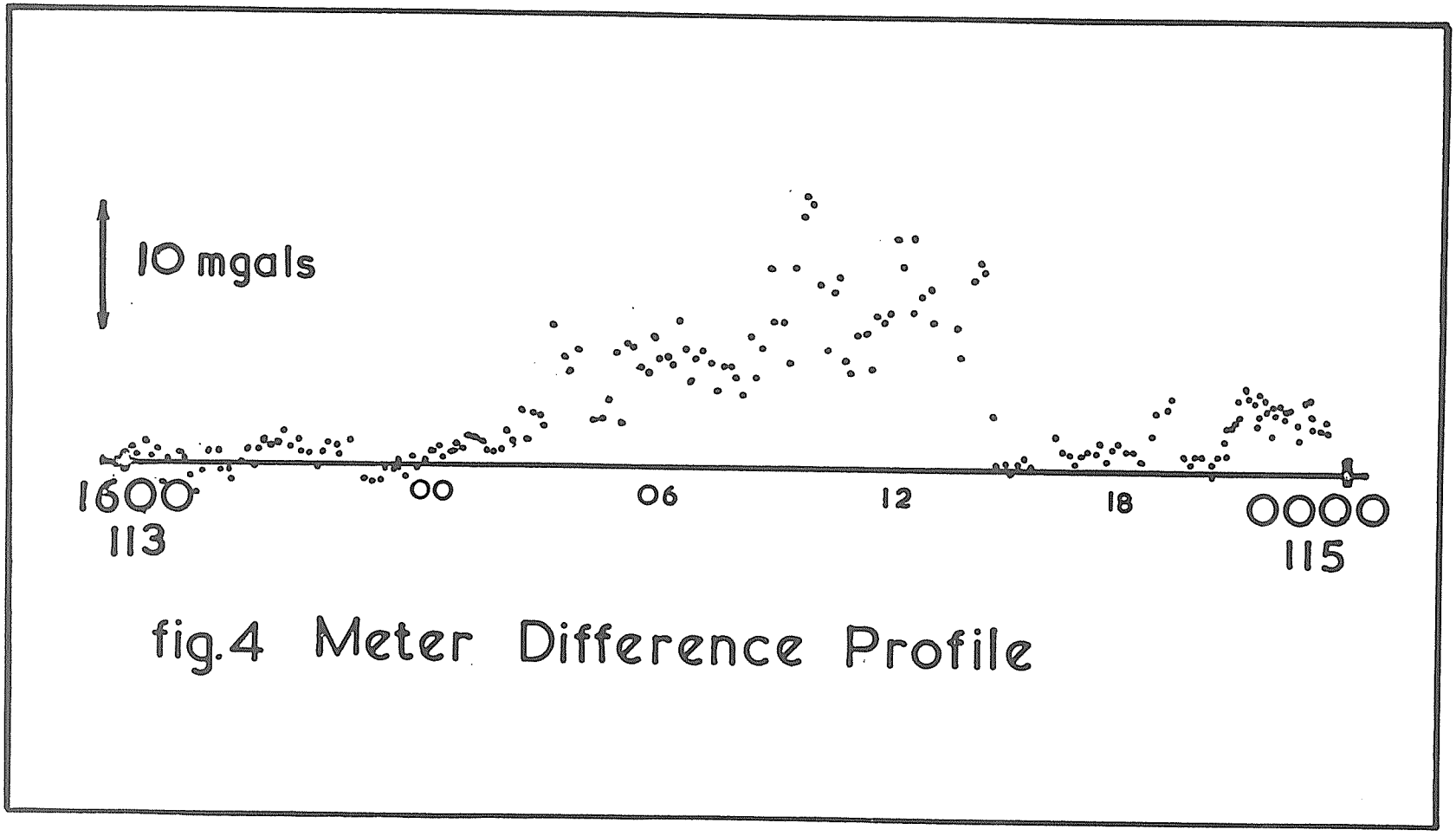
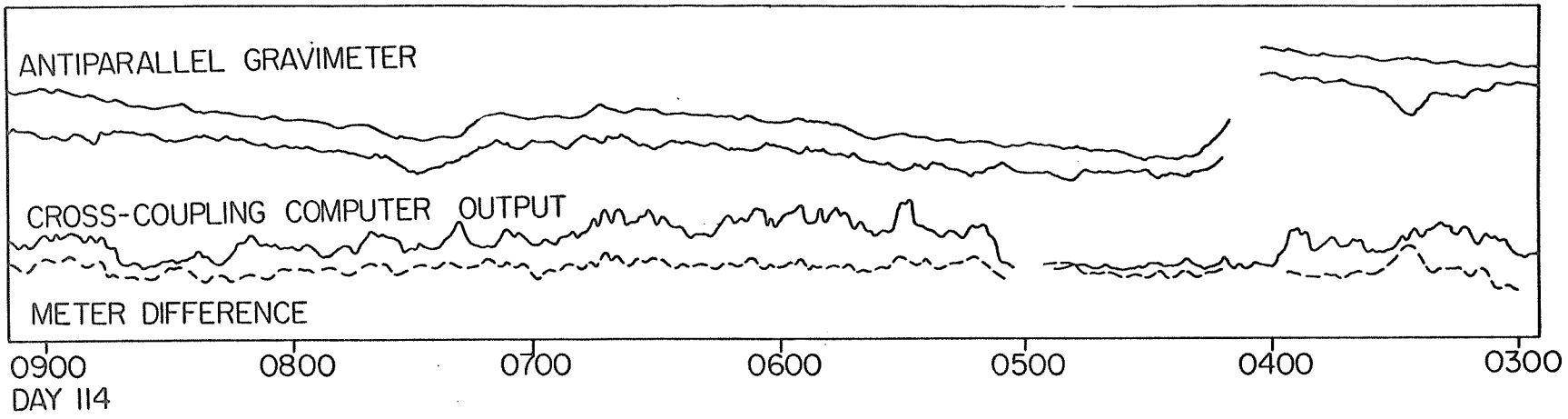
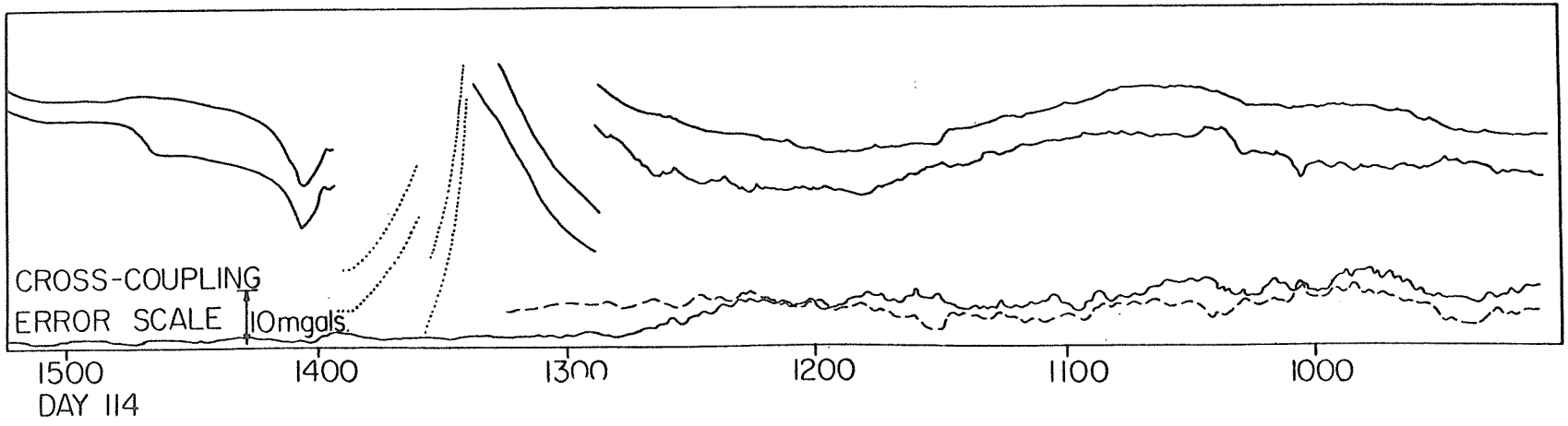


fig.4 Meter Difference Profile

Fig. 5

CROSS COUPLING COMPUTER CALIBRATION
H.M.S. HECATE APRIL 1967





Considering higher frequency components with periods of 5 to 10 minutes we begin to see a discrepancy between the two gravimeter outputs, some of which can be correlated with course alterations and platform relevelling :

0325	Relevelling the platform	1015	Course alteration
1130	" " "	1235	" "

In addition to this it generally appears that one meter gives a more irregular trace than the other. This could partially be explained by the difference in time constants mentioned earlier. It was also thought that the gyro platform might be at fault but changing the oil erected gyro dit not improve the situation.

Many of the shorter period variations which seem to be generally indicative of cross coupling are present in both traces. These have an amplitude of only 1 or 2 mgals in the section shown in fig. 6., far greater in rougher seas. The inherent irregularities in the record of the meter with the shorter time constant makes comparison difficult at times.

All that can be concluded about possible residual errors in that except for the perturbations which can be correlated with platform relevelling, they must be at a level less than 2 mgals. After further analysis of results from the entire cruise, it might be possible to isolate the cause of the smaller amplitude errors but this is not possible over the short record used in this analysis.

In conclusion it would seem that providing the gyro platforms are continuously supervised and the two meters have the same sensitivity (time constant and other characteristics) the mean profile obtained should be a very accurate one. The degree of accuracy depends purely upon the matching of the two systems. In the HECATE trial the accuracy in this respect was 1 mgal with total errors present of 10 mgals. The magnitude of this error will no doubt increase with magnitude of the cross coupling error but whether it will stay at 10 % is difficult to say.

The control for determining the reliability of the Cambridge computer is a good one providing the two sets of results are compared when the Enograph indicates that only cross coupling errors are present. All the long period variations are present in both traces and considering the accuracy of the meter difference profile (+ 0,5 mgals at any point) the correlation between the short period variations as shown in fig. 6. is extremely good and very promising. This is a sensitive test of the computer because the errors are small and the computer output is more subject to instrumental drift.

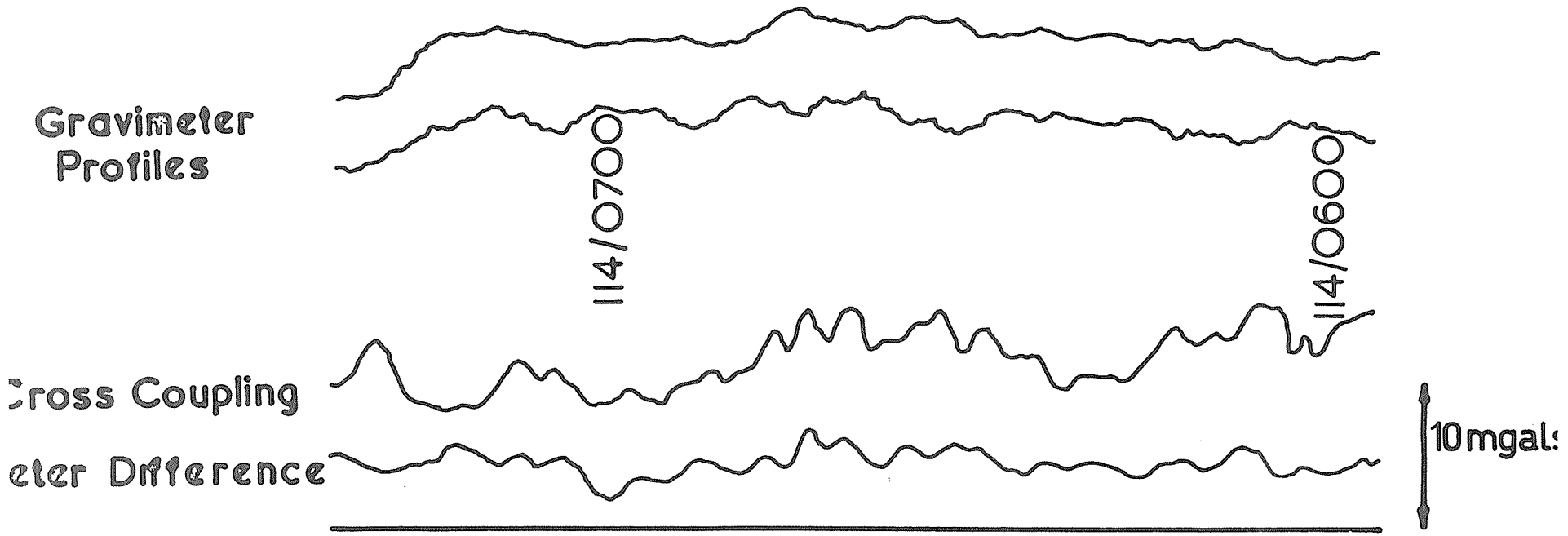


fig. 6 Detail of Cross Coupling Data

As the magnitude of the error increases the percentage error should improve. However the accuracy of the corrected profile still depends upon the original being a good one. I would estimate that the maximum error of the corrected profile using the smoother trace is 2 mgals. Most of this is due to excessive drift of the multiplier which was checked periodically throughout the cruise.

When this is replaced any corrected profile ought to be accurate to better than 1 mgal. Since Fleischer (1964) using two Askania gravimeters working in parallel demonstrated that the repeatability of the system is within 2 mgals, it is considered that the computer accuracy is within the "noise" level of the system.

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PROGRESS IN SURFACE SHIP GRAVITY MEASUREMENTS AT LAMONT GEOLOGICAL OBSERVATORY

M. TALWANI

(Lamont Geological Observatory, Columbia University
Palisades, N.Y. USA)

We summarize below some of the recent work in surface ship gravity measurements at Lamont Geological Observatory.

Errors in measurement with a Graf-Askania seagravimeter.

We have recently developed a cross coupling computer (Talwani, Early, and Hayes, 1966) which continuously computes the cross coupling correction for the Graf-Askania seagravimeter. The basic element of this computer is a multiplier which multiplies voltages proportional to the angular beam displacement, and the surge acceleration. The basic block diagram for this computer is shown at the top in fig. 7.

Two changes were subsequently made in the computer. Askania informed us that the static sensitivity of the gravimeter is approximately 0.65 sec of arc/mgal rather than 1.0 sec of arc/mgal. The use of the larger value given to us earlier had led to overcorrection of the cross coupling error. The second change arose out of the finding by Jacoby and Schulze (1967) that the gravimeter beam not only rotates but also translates in response to the vertical accelerations. However, only the rotational motion gives rise to the cross coupling error. According to Jacoby and Schulze an approximate correction can be made by passing the beam signal through a low pass filter with time constant T = 0.3 sec. This modification is shown in the middle block diagram in fig. 7 ; and analog computers with this modification are at present being used to obtain the gravity signal corrected for the cross coupling error in real time aboard R/V VEMA, R. D. CONRAD, and USNS ELTANIN.

Fig. 8. shows a 75 min section of the gravity record obtained with Graf-Askania meter GSS 2-25 aboard USNS ELTANIN. Both the uncorrected gravity trace and the trace corrected for cross coupling are shown. Note that the corrected trace is smoother as far as the apparent short term fluctuation in gravity are concerned.

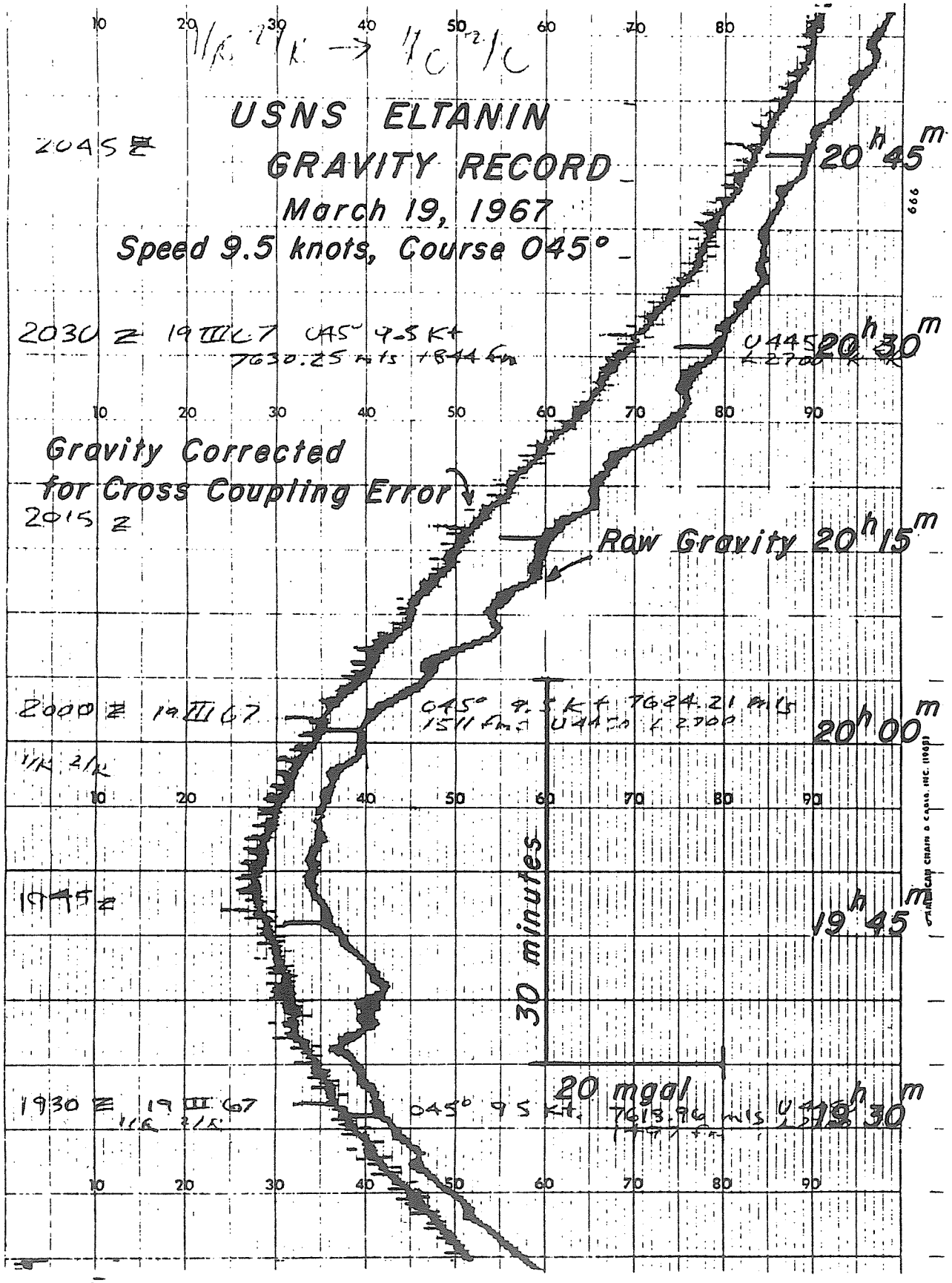
USNS ELTANIN
GRAVITY RECORD
March 19, 1967
Speed 9.5 knots, Course 045°
Gravity Corrected
for Cross Coupling Error
Raw Gravity
20h45m
20h30m
20h15m
20h00m
19h45m
19h30m
30 minutes
20 mgal

Fig. 8

The short term fluctuations still remaining in the corrected trace may be caused by incorrect calibration of the cross coupling computer ; however, we consider it more likely that they are caused by other errors such as the off-levelling errors which may be present.

If the gravimeter is not accurately linear in its response to the vertical accelerations a non-linearity error results. In the latest version of the Graf-Askania meter, a correction for non-linearity is applied by using a linearization diode in the filter network. Since this error equals $\underline{K}.\ \underline{Beam}^2$ where $\underline{K}$ is a constant and $\underline{Beam}$ represents the amplitude of beam motion, an alternative way for making this correction is possible by modifying the cross coupling computer to perform the multiplication $\underline{Beam}.\ (\underline{K}.\ \underline{Beam} + \underline{Surge})$. This is illustrated in the bottom block of fig. 7. and would be useful where the electronics supplied by Askania for filtering etc. are not used.

An analog computer for the off-levelling error is required to compute the instanteous product of the horizontal acceleration and the off level angle. If α is the pitch off level angle, the require product is $\ddot{X}.\ \alpha$. (There is a similar term for the roll off-levelling error). The pitch off level angle α can be considered to consist of α_{servo} which represents the lag of the servo system of the stable platform with respect to the gyroscope which it is trying to follow, and α_{ref} which represents the departure in the verticality of the vertical reference used to erect the gyroscope, that is, $\alpha = \alpha_{servo} + \alpha_{ref}$.

The electrical analog of α_{servo} is available as a part of the stable platform electronics ; and we have in the past computed the error $\ddot{X} \cdot \alpha_{servo}$ (Talwani, Early, and Hayes, 1966) and found that it seldom exceeds 1 mgal for the Anschutz gyrotable. The angle α_{ref} depends on the horizontal accelerations (amplitude and period) ; it also depends on the parameters of the erection loop for the gyroscope. For the Anschutz electrically erected gyroscope two parameters are involved - the time constant of a low pass filter in the erection loop and τ_k the gyro time constant. The time average of the error given by $\ddot{X}.\alpha_{ref}$ has been computed for the case $\tau_k = 30$ sec and T = 120 sec or 310 sec. Assuming that $\ddot{X}$ is sinusoidal and has an amplitude of 50 gals or 100 gals, computations have been made for periods of 1 to 20 sec for $\ddot{X}$. The resulting curves are plotted in fig. 9. If large horizontal accelerations are present and high accuracy is desired, it is clear that the off-levelling error has to be evaluated. Block diagrams which show how this might be done, incorporating both α_{servo} and α_{ref} are given in fig. 7. We have not yet built analog off-level computers but plan to do so in the near future.

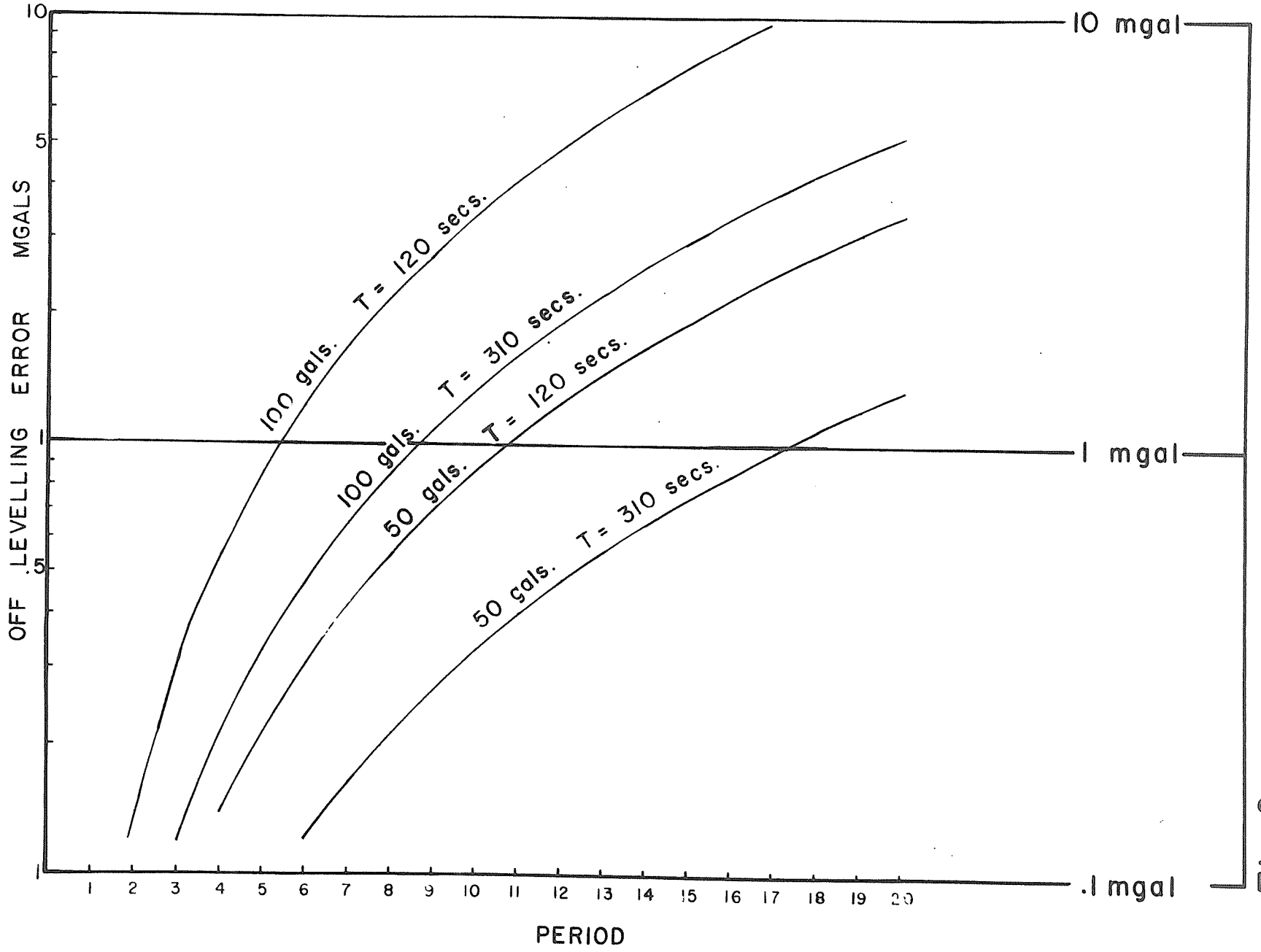
10 mgal
1 mgal
.1 mgal
100 gals. T = 120 secs.
100 gals. T = 310 secs.
50 gals. T = 120 secs.
50 gals. T = 310 secs.
OFF LEVELLING ERROR MGALS
10
5
1
.5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
PERIOD

Fig. 9

Accuracy tests

A test of the accuracy of the Graf-Askania seagravimeter GSS 2-25 mounted on an Anschutz gyrotable (with an electrically erected gyro) was made aboard USNS ELTANIN in March, 1967. A grid survey was run with lines about 100 N. miles long and gravity values were compared at 54 track intersections. A cross coupling computer was used but no correction was made for off-levelling errors. Askania electronics were not used and on some of the legs where vertical accelerations were large, non-linearity errors of about 1 or 2 mgal were present. Navigation was based on U.S. Navy's satellite navigation system ; however since only one satellite (instead of the normal 3) was operational and fixes were obtained only at the ends of the legs, considerable navigational uncertainties existed.

Poor navigational accuracy contributed to large errors in the computed Eötvös correction. In addition, because of large gravity gradients in the area, it also contributed to large errors incomputed gravity values.

A histogram of discrepancies of computed gravity values at intersections is shown in fig. 10. Almost half of the intersections agree to 2 mgal or better and almost two thirds of the intersections agree to within 3 mgal.

Comparison with satellite results

We have compared the gravity field obtained from satellite derived spherical harmonic coefficients with surface ship gravity values average over 5° squares (of latitude and longitude) in the Atlantic and Indian Oceans, both fields being referred to the International Ellipsoid (Talwani and Le Pichon, in press). The satellite derived gravity field based on the spherical harmonic coefficients given by Gaposchkin (Kaula, 1966) are given in fig. 12. while the averaged gravity values in fig. 11. are based on data collected by Lamont Geological Observatory ships R/V VEMA and R. D. CONRAD as well as submarine pendulum measurements (Vening Meinesz, 1948 ; Worzel, 1966). We have not used data obtained by Snellius (Strang Van Hess, 1967) in fig. 11., but a chart including this data does not differ significantly from fig. 11. A comparison of fig. 11. and 12. shows agreement in the broader gravity features.- a low in the western north Atlantic and a high over the Mid-Atlantic Ridge north of 35°N. As one might expect, the surface ship gravity map shows much greater detail. We have made similar comparisons for the South Atlantic and the Indian Ocean and plan to make a spherical harmonic analysis when all our data in the Pacific Ocean have been reduced.

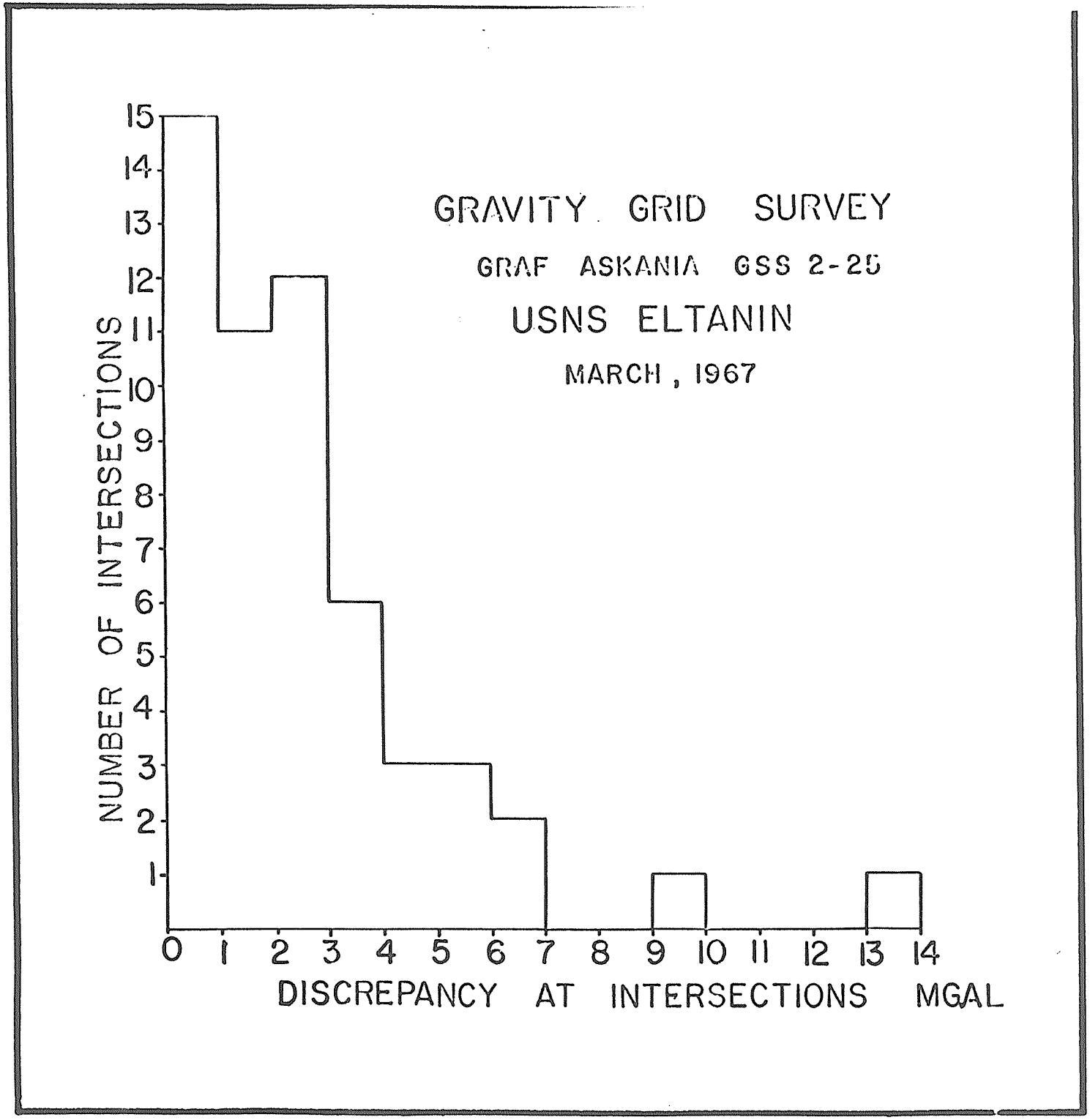
GRAVITY GRID SURVEY
GRAF ASKANIA GSS 2-25
USNS ELTANIN
MARCH, 1967
NUMBER OF INTERSECTIONS
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
DISCREPANCY AT INTERSECTIONS MGAL

Fig. 10

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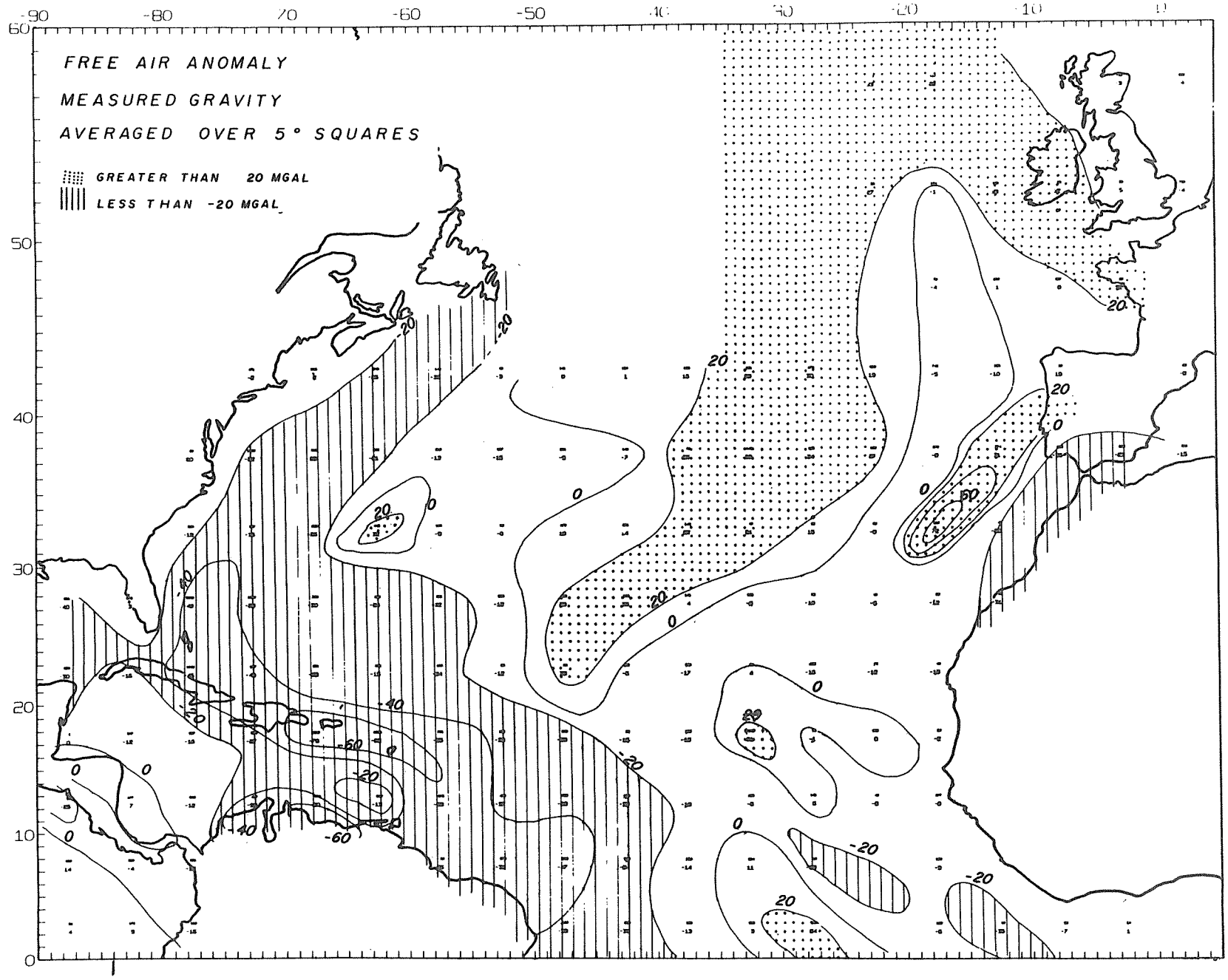
FREE AIR ANOMALY
MEASURED GRAVITY
AVERAGED OVER 5° SQUARES
GREATER THAN 20 MGAL
LESS THAN -20 MGAL
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
60
50
40
30
20
10
0

Fig.11

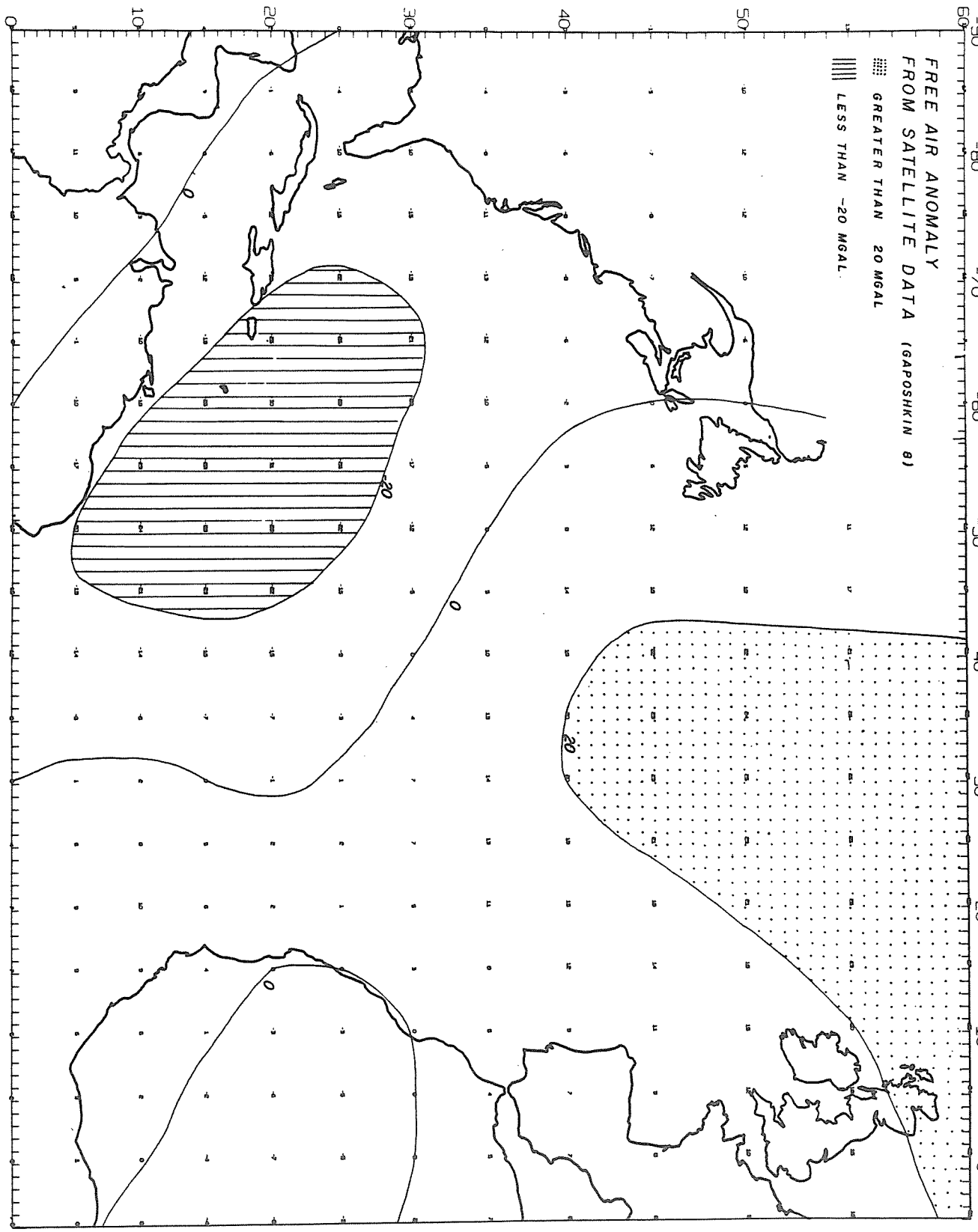
FREE AIR ANOMALY
FROM SATELLITE DATA (GAPOSHKIN 81)
GREATER THAN 20 MGAL
LESS THAN -20 MGAL
0
10
20
30
40
50
60
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
20
0
20
0

Fig. 12

REPORT ON THE CONTINUATION OF THE S.C. "GRAVIMETRICAL TESTWORK" IN THE ITALIAN WESTALPS

E. TENGSTRÖM

(President of SSG 16 of IAG)

The progress of the work in Uppsala for assembling data - gravimetrical, topographical and astrogeodetic - to be used by different groups of interested scientists for comparing gravimetrical deflection differences with the corresponding deflection differences in ED over a test area in the italian Westalps - has been reported at regular intervals (gravimetrical conferences : Trieste 1962, Paris 1962, Berkeley 1963, Prague 1964, Uppsala 1965, Paris, 1965, Prague 1966). At the IGC-meeting in Paris 1965 the total material was presented and approved as being the best available one for the investigations defined above.(1)*.

At the General Assembly of IAG in Lucerne 1967, some results from various groups of investigation were reported, but no final conclusion about the theoretical and practical values of different approaches could be made. In a resolution of IAG during same Assembly, it was stated, that an improvement of the results in the testwork could be achieved, if the old longitudes in the area could be remeasured with modern facilities. Also should the areas around the astrostations be covered with denser gravity information (Resolution n°26). The Italian Geodetic Commission was asked to help furnishing these additional data. As president of SSG 16, I am especially grateful to the Italian Geodetic Commission because of its readiness to help the study work to be carried on with improved gravimetrical and astrogeodetical material. It did not last long my arrival home before I got a positive answer at my appeal, expressed in resolution n°26. The improved material will be utilized for the second computation over the area, which is going to be started as soon as a sufficient amount of results from the first computation is available, enabling a primary comparison between the methods to be made.

The following groups, representing various methods, have delivered partial results of the gravimetrical deflections at all or for a part of such astrostations, where ξ_{ED} and η_{ED} are given, namely :

* See References p. I - 28.

I) Molodenskij's method, directly used or with modifications (Pellinen, Bursa, Pick and Pola).

II) Arnold's method (Arnold, Stange).

V) Rudzki's reduction (Tengström, Haller).

The results from these groups were more or less completely presented during the General Assembly of IAG in Lucerne.

No results from the group using the Model Earth method (IV) of de Graaff-Hunter have been received as yet. It is my hope that we shall get some data from this team (Morelli, Glennie, Carozzo) in the next future.

Bjerhammar's method (group III), which has been applied to the Westalps material by Reit, seems to give good convergence in the downward continuation procedure, and the results, recently given to me, have been computed, using the Bouguer field as an accepted gravity model for constructing necessary surface anomaly information.

An interesting contribution from the Woollard group (VI), which is probably going to participate closely in the common work for the second computation using a better material, has been given to us by L.E.Wilcox, who deals with the possibility of improving the short wave Bouguer interpolation by means of a method, called "analytical geological gravity interpolation" (2). For the regional topographical correlation effect he uses Woollard's wellknown formulas e.g. (3).

The results presented by I, II, III and V are the following :

I) Pellinen (4) has computed what he calls the zero order approximation of gravimetrical deflection components for all astrostations. This means nothing else but reducing the surface anomalies by the condensation method and using normal free-air gradient. The correction for the restauration of topography is made after applying Vening Meinesz' formula to aforesaid anomalies. Interpolation is made in the Bouguer field. Pellinen regards de Graaff-Hunter's Model Earth method as an improved special case of this "zero approximation procedure". I have been promised to have Pellinen's numerical results within a short time. Additional computations of first and second order approximations using directly the Molodenskij method and also the method of Aranov-Bjerhammar, are anticipated, but Pellinen hesitates to make these computations before a denser gravity material is available in the surroundings of the astrostations (see above mentioned offer from the Italian Geodetic Commission).

Bursa (5) has carried out a similar zero order computation, which was partly completed before Pellinen's. He was the first one to detect a great error in the η_{ED}-value for station n°40 (Bric Torniola), probably depending upon a wrong astronomical longitude value here. According to Burša, the astrogeodetic η-value at point n°40 should be approximately + 20" instead of + 5".33. More accurate corrections have been found by Pick and Morelli (6), who give there η_{ED} values for n°40 equal to +15" and + 16".2 respectively. The information about Morelli's work was given to me by Pick. Pick and Pola (7 - 8) reported in Lucerne numerical results achieved, after applying Molodenskij's method up to G_1-term for computing gravimetrical deflections in the test area, together with a very interesting review of similar investigations in the Hohe Tatra, which are based on a more detailed local gravity survey. They also discuss the influence on the gravimetrical deflections from different sources of errors. Pick and Pola have computed the ξ_g and η_g values inside a circle of radius 85 km round the centre of the area (45°N, 8°30 E.G.) ξ_g has been calculated for nrs 14, 19, 20, 30, 34b, 37, 38, 40, 45, 46, 48, and 50, the other points being supposed to have wrong ED-data. η_g was calculated for nrs 19, 20, 30, 33, 34bis, 37 and 45, where η_{ED} -values were available with sufficient accuracy. He also made a definitive computation of 40, and now obtained + 17".6.

Pick's and Pola's investigation is according to my opinion - the best contribution to the test area work achieved as yet.

This is an important work, and I am glad to know, that, with a better material, the members of this team will participate also in the second computation, enabling them to demonstrate still more clearly the practical advantages of Molodenskij's method. The surface gravity material (true free air anomalies), used by Pick and Pola have been constructed from the distributed Bouguer model, interpolating the necessary terrain corrections by means of Pick's method (9). Pick and Pola have also used a classical topographical reduction + restauration of topography. The results are closely the same, and the m.s.q. also. One remark only on this interesting work :

It is a pity that n°17 could not be added to n°14, because the irregular topography in the surrounding of these points (only 7 km apart) had been able to give a better demonstration of Molodenskij's method and its accuracy. This pair is the best one in the whole area when checking various methods and their reliabilities. A very accurate determination of the astrogeodetical values of ξ and η at these points together with a detailed gravimetrical (and ev. improved topographical) survey next to them is highly desirable for the second computation (see above about the promise from the Italian Geodetic Commission).

Pick and Pola end their report with two essential recommendations for creating a gravity material to be used in the next step :

1) Inside a circle round the center with radius 80 km a gravity net with a density of 1 point per 5 km^2 should be established.

2) In the nearest environment of the astropoints, approximately 5 - 10 gravimetric points be established. (It is not defined what the authors mean by "nearest neighbourhood", reporter's remark).

II) Arnold, Montag and Stange have clearly understood the great importance of using the pair 14, 17 for checks on theoretical methods and numerical procedures. Their report in Lucerne (10) expresses the following opinion about the whole topographical material given to their group (as to all other groups) : "Summarizing the results, it was proved, that the topographic maps suffice for determining our correction term for all points of WestAlps Test Area. Whether the gravimetric material will suffice for computing the main term of Vening-Meinesz integral must be proved by other investigations". As known, Arnold's method uses, in the computation of ξ_g and η_g from Vening Meinesz' formula, true free air anomalies Δg_F at the surface, corrected by

$$KG\ (\Delta g_F) = -\frac{h}{2\pi} \iint \frac{\Delta g_F - (\Delta g_F)_Q}{r^3}\, dF = 2Gh\sigma, \text{ where } h = H_Q - H_P$$

the height difference between Q, or, the point where the gravity anomaly has to be corrected, and P, that is the point, where the deflection has to be computed, r is the distance between integration element dF with anomaly Δg_F and Q, σ is the anomaly of mean curvature at Q.

Unfortunately, only KG (Δg_F) round the station are reported, no calculation of the main term in ξ_g and η_g has been made by this group. Pick and Pola, however, in using Molodenskij's method, have computed it for station 14. As soon as I receive the values of this zero-term and the G_1-term from them, it will be possible (after a local integration) to compare Arnold's results for this point with the results of Pick and Pola and with the results of the Uppsala group (V, see below). It will be especially interesting to see, how well the G_1 terms of Pick and Pola agree with Arnold's term.:

$$\begin{pmatrix} \xi' \\ \eta' \end{pmatrix} = -\frac{\rho''}{2\pi} \iint KG\ (\Delta g_F) \begin{pmatrix} \sin A \\ \cos A \end{pmatrix} d\psi\, dA$$

remembering, that KG (Δg_F) has been evaluated in a simpler way than in Molodenskij's method, using the linear regression $\Delta g_F = a + bH$ with $b = 0.1$ for interpolation of surface-anomalies, an approximation, which may be doubtful in certain areas.

V) The Uppsala group, using Rudzkianomalies and restauring the topography automatically reaches at least first order approximation for the surface deflections (G_1-term), by considering the detailed topography (down to - at least-squares of size 1' x 1', also by correcting the free air reduction in the Rudzki anomalies by successive approximations of the curvature anomalies along the "2.67-geoid", that is the geoid, given by the assumed density 2.67 for the land topography and a topography at sea, with depth $\frac{2.67 - 1.03}{2.67} D$, where D is the actual depth. The group has used Tengström's formulas (1) for the derivatives $\frac{\partial^2 n}{\partial x \partial y}, \frac{\partial^2 n}{\partial y^2} - \frac{\partial^2 n}{\partial x^2}$ transformed for anomalies in the geographical grid.

A generalized field, constructed by continuous averaging of 4 5' x 5 - means around each point in the 5''x 5' - system has been used for these computations. The description of the field within a square 20'lat x 30' long with computation point at its centre has been made analytically by an ortogonal polynomial of degree 10 + 10 (11 x 11 points). Outside the 20' x 30' - square, mean anomalies of 5' x 5', 20' x 30', 1° x 1° and 5° x 5° have been used. The effect from the 5° x 5° - squares is extremely small, and could always have been neglected. Integrating the aforesaid derivatives, ξ and η relative the centre for all 5' x 5' - points have been obtained.

Corresponding surface values have been calculated by adding the following corrections :

1) Local field correction.

2) Transfer to surface in free air, using "geoidal" data.

3) Correction for horizontal attraction effect at the surface, when restauring topography.

As an example, the Δg - difference between 14 and 17 has been computed for this report. Δg and Δg_{ED} differ only with 0".3, with 1' x 1' topographic model used. From the results of a corresponding absolute deflection computation at the centre of the area on the generalized "geoid", and applying above-mentioned corrections, we may derive absolute surface values for the astrostations. Comparing these values with the given ED-values, it is possible to compute the correction to the ED - deflections in Potsdam. The N values for the astrostations has also been derived. In the absolute calculations the 5° x 5° Rudzki anomalies (= free air anomalies) have been taken from the combined gravimetrical and satellite solutions, given by Kaula (2) Köhnlein (13).

The results are the following for the centre of the area :

$\xi_{abs} = - 4".4$

$\eta_{abs} = +11".9$ with Kaula's solution

$N_{abs} = +57.8$ m

$\xi_{abs} = -4''.3$

$\eta_{abs} = +11.4$ with Köhnlein's solution

$N_{abs} = +57.1$ m

The absolute values in Potsdam have been found to be, preliminary :

$\xi_P = +0''.5$

$\eta_P = +2''.9$

$N_P = +57$ m

using the mean of aforesaid values at the centre.

The table at the end of this report gives our results for the differences $\xi_{abs} - \xi_{ED}$ and $\eta_{abs} - \eta_{ED}$ at 8 resp. 5 points in the test area, with more reliable Bouguer information. The results are only preliminary.

I am very sorry, that group IV has not been able yet to contribute to the numerical comparison of results. De Graaff-Hunter's method should be a very practical one, and I am sure, that a numerical result with a description of the computation procedure would be able to convince still more scientists of the practical advantages of the Model Earth Method. An attempt to simplify this method by condensing all topography (additional positive and negative surface density with total sum of coating masses = zero) has recently been made by Bhattacharji(14.) He applies this procedure in order to reduce a supposed error from assumed wrong density. At the same time, however, he increases the error from the utilization of normal free air gradient instead of true value for the level surfaces after condensation, which maintains or even increases the original complexity of level curvature distribution along the Model Earth surface.

As regards group III, I have contacted Prof. Bjerhammar, who will probably also deliver numerical surface values for a number of astro-stations in the next future. His method is very interesting, because it shows once more, that downward continuation is still possible in the most rugged regions of the test area.

It is my hope, that in coming Bulletin d'Information, I shall be able to report in details about the progress of the testwork, also that part, done by the groups III and IV, Bjerhammar will also deliver material for the contribution of 5° x 5° - squares to the absolute values of ξ , η and N, the material being taken from his world wide gravimetrical and satellite solution, presented to us in Lucerne (15).

Addendum :

When the interpolation of point Bouguer anomalies should be made at Ohio State University by Dr. Rapp in 1965, I asked Prof. Uotila to carry out the prediction for the 5' x 5' grid of the 200 km circle, if possible taking into account an eventual correlation between terrain corrected Bouguer and topography. This was not done, however. The 5' x 5' Bouguer field has actually been predicted using auto-correlation only. In the fall of 1967 I started to check an eventual linear regression in the point anomalies with height, and I found, that in certain areas significant positive or negative regression coefficient are present.

The effect of using density 2.67 instead of correct mean densities, given in the Italian density map by Vecchia "Densità media in Italia sino al livello del mare", seems to be very small. The complexity of the geological structure above and below geoid is probably responsible for the correlation. It is of importance, that in the next computation, all known geological effects be taken into account by interpolating the Bouguer anomalies, if the gravity net is not dense enough at that time (see n°2.).

For the present I have tried to improve the Bouguer picture by regression analysis and geometrical interpolation of b and a $\simeq \Delta g_B - bH$, so that a basic material of a - and b - values will be given to all groups in a recomputation of such contributions, which emanate from the 5' x 5' squares, (ev. also some 20' x 30' squares). This new Bouguer material will be delivered to all interested groups after its completion, probably during April or May of this year. Our own results from the new material will appear in May.

Responsible for all computations, done by the Uppsala group has been L.A. Haller, M.Sc., who has also taken part in the theoretical investigations. The high speed computer used, was the CDC 3600 of Uppsala University. All programming has been carried out by Haller in a very meritorious way.

Table of surface deflections in the test area

N°	Abs. ξ''_g	ED ξ''_A	$\xi_g - \xi_A$	Abs. η''_g	ED η_A	$\eta_g - \eta_A$
19	-20.2	-20.7	+ 0.5	+ 3.4	+ 0.5 +	+ 2.9
20	-20.0	-20.9	+ 0.9	+ 3.5	+ 1.0	+ 2.5
33	- 8.7	- 8.3	- 0.4	+17.8	+14.4	+ 3.4
37	+ 0.2	- 2.9	+ 2.7	+ 5.7	+ 2.2 ++	+ 3.5
40	- 1.0	- 2.4	+ 1.4	+20.1	--	--
45	- 3.1	- 5.6	+ 2.5	+ 1.8	- 1.7	+ 3.5
46	- 3.4	- 5.5	+ 2.1	+ 1.5	--	--
48	- 6.7	- 7.1	+ 0.4	- 1.3	--	--

+) Not in the WestAlps list. Taken from Levallois "Liste des stations de déviation de la verticale, rattachées au Réseau Européen (given in whole seconds only).

++) Wrong astro-longitude. Taking the mean of $\eta_g - \eta_A$ for the points 19, 20, 33, 37 and 45 we get for the centre of these points and absolute correction to ED, equal to + 3.2. Subtracting this from η_g at n°40, we obtain a probable value of η_A for this point, equal to + 16".8 (of aforesaid values of Bursa, Pick and Morelli).

If we do same averaging for $\Delta\xi$, we get + 1".3 as absolute correction at the centre of 19, 20, 33, 37, 40, 45, 46 and 48.

Using the values of N_{abs} obtained for these points, we get at the same centre a correction to the ED geoid, which transfered to Potsdam, there gives N_p = 57 m together with ξ_p = 3".9, η_p = 4".7, the last values being higher than any one obtained as yet. To investigate the reliability of these Potsdam corrections, a detailed analysis of the errors emanating from the material, used, is now going on in Uppsala. See also (8).

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