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EARTH TIDE ANALYSIS PACKAGE ETERNA 3.0

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This is to announce that the new version 3.0 of the earth tide analysis package ETERNA is available. Several parts of the ETERNA earth tide analysis package have been rewritten and several other pieces have been added with the most recent update ETERNA 3.0, and we believe that there has been achieved a substantial improvement with respect to flexibility and operational comfort. The earth tide analysis package ETERNA version 3.0 consists of the programs

ETERNA:	earth tide analysis, in FORTRAN 77
ETGTAB:	prediction of model earth tides, in FORTRAN 77
PLOTDATA:	plot of data and residuals, in Microsoft 5.0 FORTRAN
PLOTHIST:	plot of a histogram of residuals, in Microsoft 5.0 FORTRAN
PLOTSPEC:	plot of a spectrum of residuals, in Microsoft 5.0 FORTRAN
PLOTRESA:	interactive plot of residuals, in Microsoft QuickBasic 4.0

The programs files, data files and result files are distributed on three 3.5" floppy discs, together with a program manual including listings and plots on 28 enclosures. All programs may be executed on an IBM-AT compatible personal computer under MS-DOS operating system, and the programs ETERNA and ETGTAB may also be executed on a work station under UNIX operating system.

The ETERNA earth tide analysis program uses the least squares adjustment procedure with multi channel input to derive tidal parameters and meteorological parameters, and spectral analysis of the residuals to derive standard deviations of the adjusted tidal parameters. The mathematical model of the ETERNA earth tide analysis program has been developped by CHOJNICKI 1973 and modified and completed by SCHÜLLER 1976, 1977a, 1977b, 1978, 1986, and WENZEL 1976a, 1976b, 1977, 1994a, b. With ETERNA version 3.0, there may be used

- up to 85 wavegroups,
- up to 175 unknown parameters,
- up to 300 observation blocks,
- unlimited number of observations within each observation block.
- four different tidal potential developments (DOODSON 1921, CARTWRIGHT-TAYLER-EDDEN 1973, BÜLLESFELD 1985 and TAMURA 1987),
- single- or multi-channel input,
- up to five additional parameters in case of multi-channel input,
- either highpass filtering of the data or drift modelling,
- in case of highpass filtering: 8 symmetric numerical FIR filters of different length and quality are available,
- in case of drift modelling: TSCHEBYSCHEFF-polynomials of individual degree per observation block may be adjusted,

- unity window or HANN-window may be applied for the weights of the least squares adjustment,
- error estimation by least squares adjustment or by FOURIER-spectrum of residuals.

The earth tide analysis package ETERNA 3.0 is available to anybody; the package should however not be copied and given to third parties by any user. In order to cover the costs for copying and distributing the ETERNA package, a fee of 100 $ US has to be charged to university and research institutes. The ETERNA 3.0 package has been given free of charge to the International Earth Tide Center, Bruxelles, for internal use only.

Requests for the ETERNA 3.0 package should be submitted to (please use the order form on next page for your convenience):

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Order form for ETERNA 3.0 package

I hereby order the ETERNA 3.0 package for scientific use only in my university or research institution. I have added an international bank cheque of 100 $ US payable to Baden-Württembergische Bank Karlsruhe, to cover the distribution costs.

Name: _____
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signature: _____

Send this form back to: Prof. Dr. H.-G. Wenzel, Black Forest Observatory, Heubach 206, D-77709 WOLFACH, Germany.

PRETERNA - A PREPROCESSOR FOR DIGITALLY RECORDED TIDAL DATA

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Abstract

Using digital data acquisition systems connected to modern feedback gravimeters, a resolution of about 0.1 $nm/s^2 = 10^{-11}$g can be achieved for the recorded gravity signal during normal periods. But the recorded gravity signal is sometimes disturbed by steps (e.g. due to instrumental problems) and spikes (e.g. during large earthquakes). For the analysis of the data using a standard earth tide analysis program, the data digitally recorded with high sampling rate have to be decimated to hourly samples. In order to obtain precise hourly samples, the recorded data have to be preprocessed (i.e. steps and spikes have to be detected and removed, the data have to be interpolated during strong earthquakes and gaps and the data have to be filtered and decimated to hourly samples). The data preprocessing is currently carried out in different ways and often considerable manual editing is necessary during the data preprocessing.

In the paper, a semi-automatic preprocessing program package called PRETERNA 3.0 is described, which uses a remove-restore technique in order to detect and correct very small errors. The data digitally recorded for one earth tide sensor and one barometer with 1 min sampling interval are calibrated and model tides using a priori tidal parameters and the air pressure effect on gravity using an a priori regression factor are removed. The remaining signal, i.e. the sensor's drift plus noise, is subsequently checked and corrected for steps, for spikes and for gaps. The a priori thresholds for steps and spikes are controlled and updated by the preprocessor using estimated statistical parameters, which depend on the noise level of the recorded data. Finally, the a priori tides and the a priori air pressure contribution is restored and the data are numerically filtered and decimated to 5 min sampling interval and subsequently to 1 hour sampling interval. The data preprocessing with PRETERNA is semi-automatic, because it may be controlled und updated by the operator between different computation steps assisted by a screenplot program. The PRETERNA preprocessor has been applied successfully to several recorded tidal gravity data sets; some examples are given in the paper.

1 Introduction

The aim of earth tide observations is to improve our knowledge about the Earth (primarily the solid Earth). We do that by observing the response of the Earth to the tidal forcing function with a sensitive instrument and by comparing the observations with a model of the universe, including the Earth (Fig. 1). This is generally carried out using a standard earth tide analysis package (e.g. WENZEL 1994a, b).

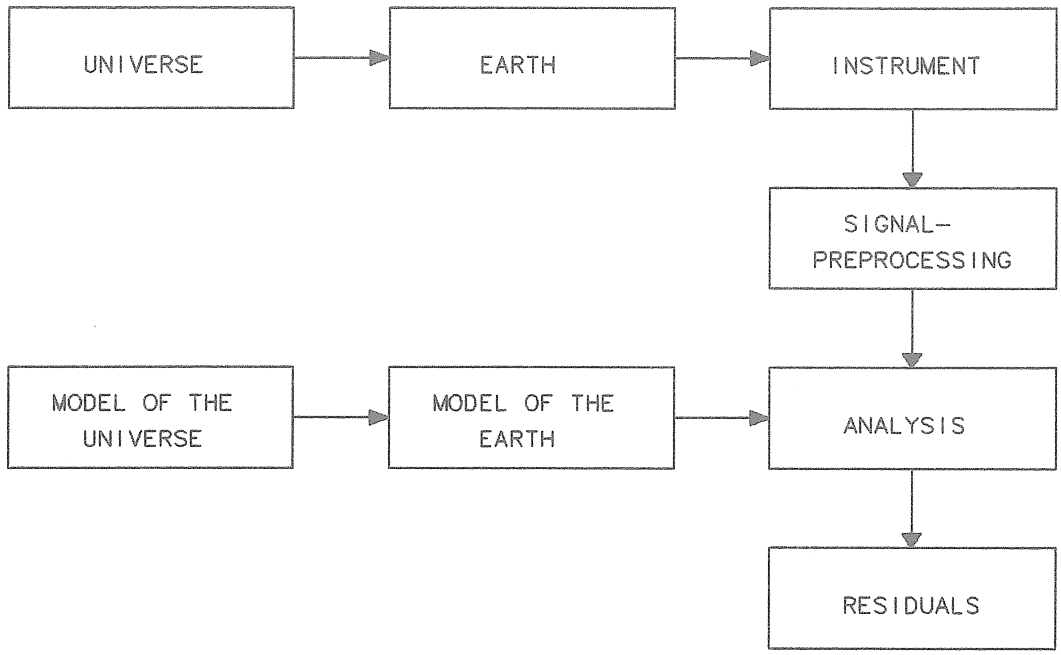

Figure 1: Aim of earth tide observations

The instrument we use nowadays for the observations consists of an earth tide sensor, an analog to digital converter, a clock and a personal computer to store the data. The earth tide sensor (e.g. gravimeter, tiltmeter, strainmeter) usually provides an analog voltage as output, which is proportional to the earth tide signal to be observed. This analog voltage is generally analog filtered (to prevent alias effects) and digitized at high rate (0.1 ... 1 sample per second) using an accurate analog to digital converter, controlled by an accurate clock. The digital data are stored (eventually after numerical filtering and decimation to a lower rate of e.g. 1 sample per min) with a personal computer.

Because it is convenient to use a sampling interval of 1 hour for the earth tide analysis, the data digitally recorded with high rate (1 sample per min or higher) have to be decimated after appropriate numerical filtering to 1 hour interval. Additionally, one has to calibrate the data, to remove eventual steps, to remove eventual spikes e.g. during earth quakes and to fill eventual gaps. This is the task of the earth tide data preprocessing and may be carried out using the program package PRETERNA 3.0, which is described in section 2.

Due to the rapid development of personal computers and workstations, they have become a powerful and cheap tool for the processing of earth tide observations. Some of these platforms have a higher computational speed than many of the mainframes at the computing centers do have. Therefore the PRETERNA preprocessing package has been established and tested on personal computers under operation systems MS-DOS and MS-WINDOWS. The main program can operate on workstations under operation system UNIX.

2 The earth tide preprocessing package PRETERNA

In the following we describe he earth tide prepocessing package PRETERNA version 3.0 (August 1st 1993). Previous versions (1.0 .. 2.0) of this package have been distributed in 1992 to a very limited number of individuals for testing purpose only. The earth tide data preprocessing program package PRETERNA consists of the programs

PRETERNA : earth tide data preprocessing, in FORTRAN 77,
PREPLOT : plot of observations, in Microsoft QuickBasic 4.0.

The aim of the tidal data preprocessing is to remove high frequency noise contained in the raw data e.g. due to microseismics, earthquakes and environmental effects, but not to change significantly the low and medium frequency part of the signal (0 ... 6 cpd), because we want to use this part of the signal within the tidal analysis. Thus we cannot improve the data quality in the low and medium frequency band, except that we can avoid noise produced in the low and medium frequency band by e.g. alias effects, steps, feedback saturation during large earthquakes, etc. One should mention that the best data preprocessor is a high quality earth tide sensor, a high quality data acquisition system and the best shielding of the earth tide sensor against environmental effects one can produce. It should not be the aim of the data preprocessing to remove instrumental spikes or man-made noise from the recorded data; these disturbances should be removed by instrumental improvements, or by better shielding of the earth tide sensor, or by moving the earth tide sensor to a quiet station.

The earth tide preprocessing program package PRETERNA allows the preprocessing of 1 min earth tide data. Data which have been recorded with a higher sampling rate have to be decimated to 1 min sampling interval before starting the preprocessing with PRETERNA. The preprocessing is done with a remove-restore technique, i.e. at first we remove a model earth tide signal and a model air pressure contribution to the earth tide sensor, then we check and subsequently correct the residual signal for steps, for spikes and gaps and we finally restore the model earth tide signal and the model air pressure contribution to the cleaned residual signal (see Fig. 2). This procedure will cancel errors in the model earth tide signal and model air pressure contribution to a large extend (naturally except for the gaps, where we use the model earth tide and model air pressure contribution to interpolate the data during the gap). The corrected samples at 1 min sample interval are finally numerically filtered and decimated to 5 min samples and subsequently to hourly samples. The data processing may be carried out in different computation steps, but one may also bundle successive steps within one computation run. The result of the different computation steps may be checked using the screenplot program PREPLOT (Fig. 2).

The program source code file of PRETERNA 3.0 contains 17 subroutines and consists of 4448 records in total. The output file of program PRETERNA may directly be used to input into the earth tide analysis program ETERNA version 3.0 (WENZEL 1994a, b).

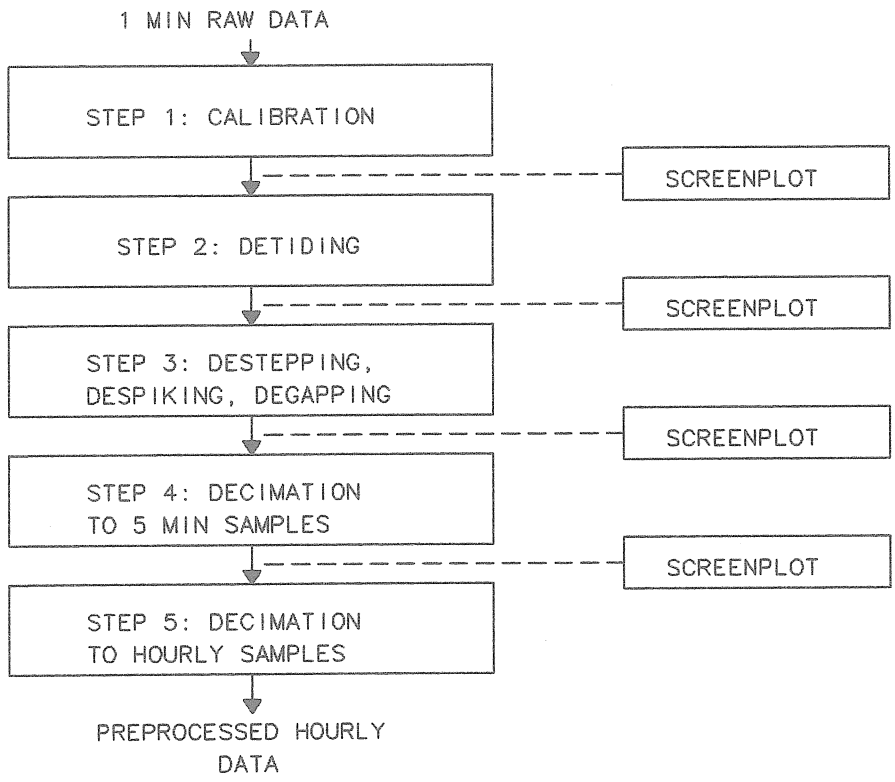

Figure 2: Block diagram of tidal data preprocessing with PRETERNA

Computation step 1:	Check the sequence of data and calibration.
Computation step 2:	Computation of model tides and drift.
Computation step 3:	Destepping, despiking and gap interpolation.
Computation step 4:	Numerical filtering and decimation to 5 min samples.
Computation step 5:	Numerical filtering and decimation from 5 min samples to hourly samples.

There may be used with PRETERNA

- as observations: tidal potential, gravity tides, tilt tides, vertical displacements, horizontal displacements, vertical strain tides, horizontal strain tides, areal strain tides, shear strain tides, volume strain tides and oceanic tides.
- a priori tidal parameters for up to 85 tidal wave groups,
- 1 additional meteorological parameter,
- 4 different tidal potential developments (DOODSON 1921, CARTWRIGHT-TAYLER-EDDEN-DOODSON 1973, BÜLLESFELD 1985 and TAMURA 1987).

2.1 Computation step 1: Sequence of data check and calibration

When reading the data, the sequence of the data is checked. There is not allowed any gap in the sequence of the data; data gaps have to be organized as data records with undefined (flagged) earth tide and/or air pressure data. We use 3rd degree polynomials to calibrate the earth tide and barometer signal from Volt to the component dependent earth tide unit and hPascal respectively. The calibrated earth tide observation is stored as channel 1 and the calibrated air pressure observation is stored as channel 2 in the formatted data output file of this computation step.

2.2 Computation step 2: Computation of model tides and drift

We compute model earth tides for the specified earth tide component at 1 min sample interval, delayed for the instrumental time lag of the earth tide sensor. These model earth tides are stored as channel 3 in the output data file of computation step 3. The model earth tides are computed from a tidal potential catalogue, with observed amplitude factors and phase leads read from input. Tidal potential catalogues from DOODSON 1921 (379 waves), CARTRIGHT-TAYLER-EDDEN-DOODSON 1973 (505 waves), BÜLLESFELD 1985 (656 waves) or TAMURA 1987 (1200 waves) may be used. For the computation of model earth tides, we use exactly the same routines as are used within the earth tide analysis package ETERAN 3.0 (WENZEL 1994 a, b). For the air pressure contribution, we use a linear correction factor α read from input (α = air pressure correction factor = negative air pressure regression coefficient, as e.g. computed by earth tide analysis). The residual signal is computed by

$$residual = observation - model\ \ tide + \alpha \cdot airpressure \qquad (1)$$

and stored as channel 4 in the output data file of this computation step.

The reason for applying air pressure corrections already in the data preprocessing is demonstrated with Figs. 3 ... 6. All data shown in the following have been obtained with gravimeter LaCoste-Romberg ET19 and barometer BMG6 at station BFO Schiltach ($\phi = 48.3306^0$, $\lambda = 8.3300^0$, h = 589 m). The station and the instruments have already been described in WENZEL and ZÜRN 1990, WENZEL et al. 1991, and ZÜRN et al. 1991. The data have been recorded with 5 s interval and 21 bit resolution on optical WORM discs und subsequently filtered and decimated to 1 min resampling interval. Fig. 3 shows the barometer signal with some short periodic air pressure variation of about 1.2 hPa. Fig. 4 shows the detided signal of gravimeter LCR-ET19 without air pressure correction. There can be seen considerable short periodic gravity variation of about 4 nm/s^2 due to the air pressure influence. If we would not correct the air pressure influence within computation step 2 of program PRETERNA, the despiking procedure in computation step 3 would remove to some extend these short periodic gravity variation. But a subsequent earth tide analysis using the air pressure as additional input channel would give large residuals at those instants where we have despiked the air pressure influence during the data preprocessing. Fig. 5 shows the detided gravity signal with air pressure correction of 3.2 nm/s^2 per hPa applied, where the air pressure influence to the gravimeter signal is removed to a large extend. The despiked gravity signal at 1 min interval is shown in Fig. 6.

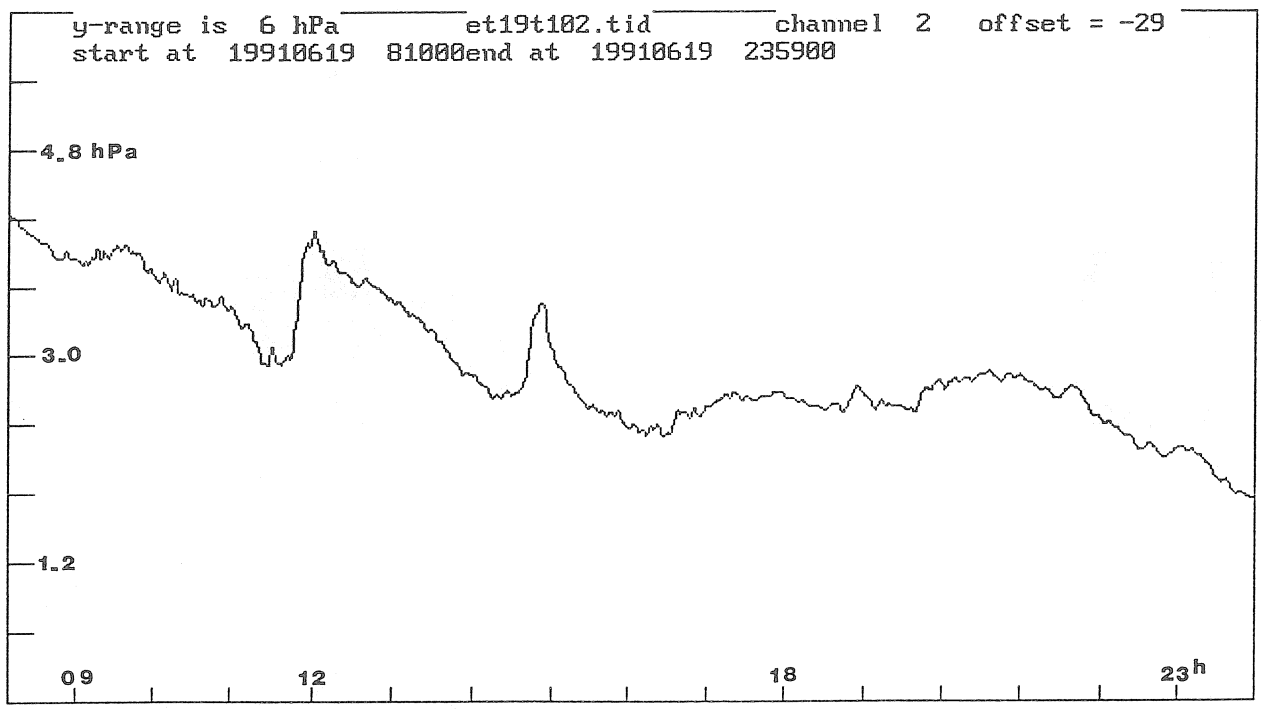

Figure 3: Air pressure at 1 min interval recorded with barometer BMG3 at BFO Schiltach 19.06.1991 08:10...23:59.

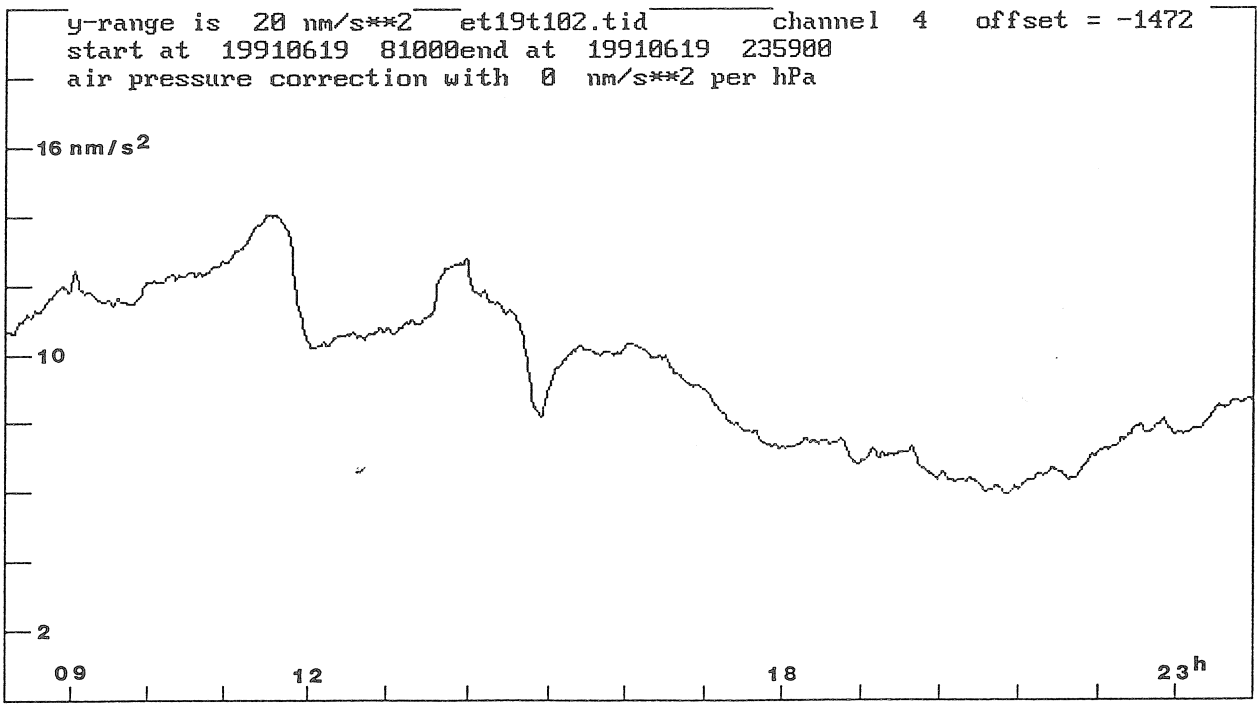

Figure 4: Detided gravity at 1 min interval recorded with gravimeter LCR-ET19 at BFO Schiltach 19.06.1991 08:10...23:59, no air pressure correction applied.

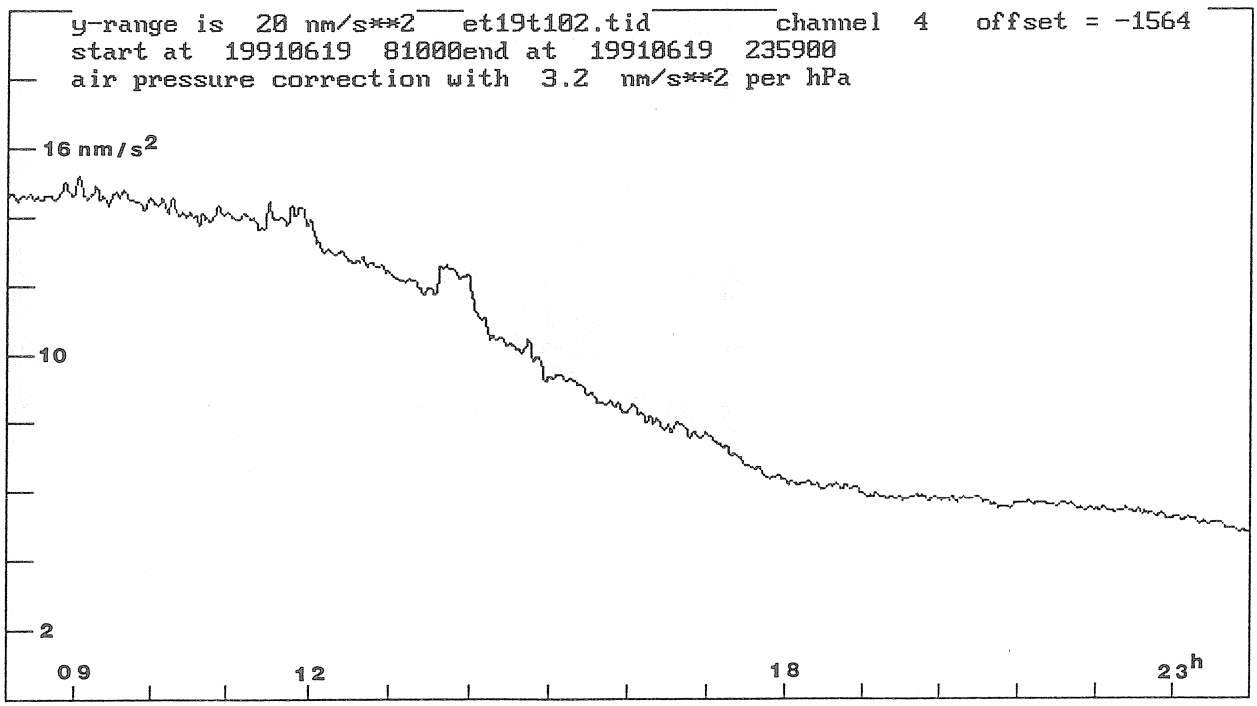

Figure 5: Detided gravity at 1 min interval recorded with gravimeter LCR-ET19 at BFO Schiltach 19.06.1991 08:10...23:59, 3.2 nm/s^2 per hPa air pressure correction applied.

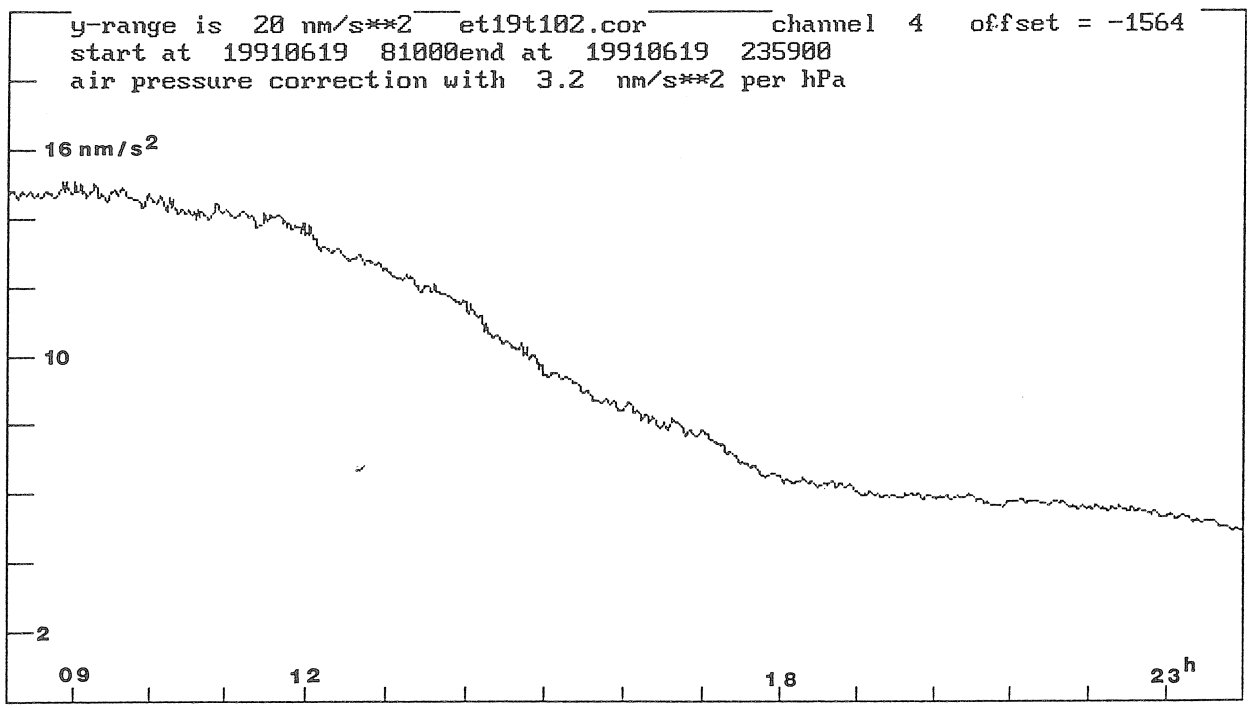

Figure 6: Despiked gravity at 1 min interval recorded with gravimeter LCR-ET19 at BFO Schiltach 19.06.1991 08:10...23:59, 3.2 nm/s^2 per hPa air pressure correction applied.

2.3 Computation step 3: Destepping, despiking and degapping

Within this computation step, the residual signal is at first destepped, than despiked and finally degapped.

Destepping:

For the destepping we compute half hourly averages of the residual signal together with their standard deviations. With these half hourly averages, an iterative search for steps with routine ETSTES is carried out. Within routine ETSTES, a 1st degree least squares polynomial is fitted over 10 hours, with two different zero degree coefficients (one for the first half of the samples and one for the second half of the samples) beeing adjusted. The standard deviations of the half hourly averages are used to derive weights for the step adjustment. The difference between these zero degree coefficients is the estimated step. A step is assumed to be found, if it exceeds three times its estimated standard deviation and if it exceeds a threshold read from input (this is for not correcting very small steps in case of very small standard deviations). Within one iteration loop for the step search, the time window for routine ETSTES is moved over the recorded time span with half an hour shift between successive calls of routine ETSTES. For the iteration loop the step with maximum signal to noise ratio is assumed to be found and subsequently corrected at the half hourly averages and the sample data. The iteration is continued until no more steps are found. An example for the destepping procedure is given in Figs. 7 and 8, showing the automatic detection and correction of a step of $24.8 \pm 0.4\ nm/s^2$.

Despiking:

The despiking is carried out in an iterative procedure searching for spikes and removing spikes using the residual signal. A 2nd degree polynomial is fitted to the 1 min samples over 120 minute time span and the maximum residual inside a central window of $\pm$ 30 min around the central time of the fit is tested against a threshold. This threshold is determined by the despiking limit ϵ read from input, if it exceeds three times the rms of fit of the previous despiking loop. The maximum residual inside central window exceeding this threshold is then added to the sample data and the fit is repeated with the time window for the fit shifted by 15 min. The initial threshold is set to 64 times the limit ϵ read from input and then subsequently divided by two for each despiking loop. Within a despiking loop, this threshold remains constant. Within each despiking loop, the time window for the fit is shifted over the whole time span of the record. If we for instance input as despiking limit $\epsilon = 2\ nm/s^2$ for a gravity record, the first despiking loop removes residuals of the fit exceeding 128 nm/s^2 only. In the second despiking loop, we use 64 nm/s^2 as threshold and we remove spikes exceeding 64 nm/s^2 only. The threshold is divided by two for each despiking loop, until it is below the initial threshold of 2 nm/s^2. If the threshold is below the initial despiking threshold of 2 nm/s^2, it is decreased by a factor of two only if it is below three times the rms of fit of the previous despiking loop. This procedure enables an automatic adaption of the despiking threshold to the noise of the record for normal recording periods. For periods containing large disturbances (e.g. earthquakes) the despiking threshold is frozen about the input threshold ϵ. An example for the despiking of a record containing an earthquake is shown in Figs. 9 and 10.

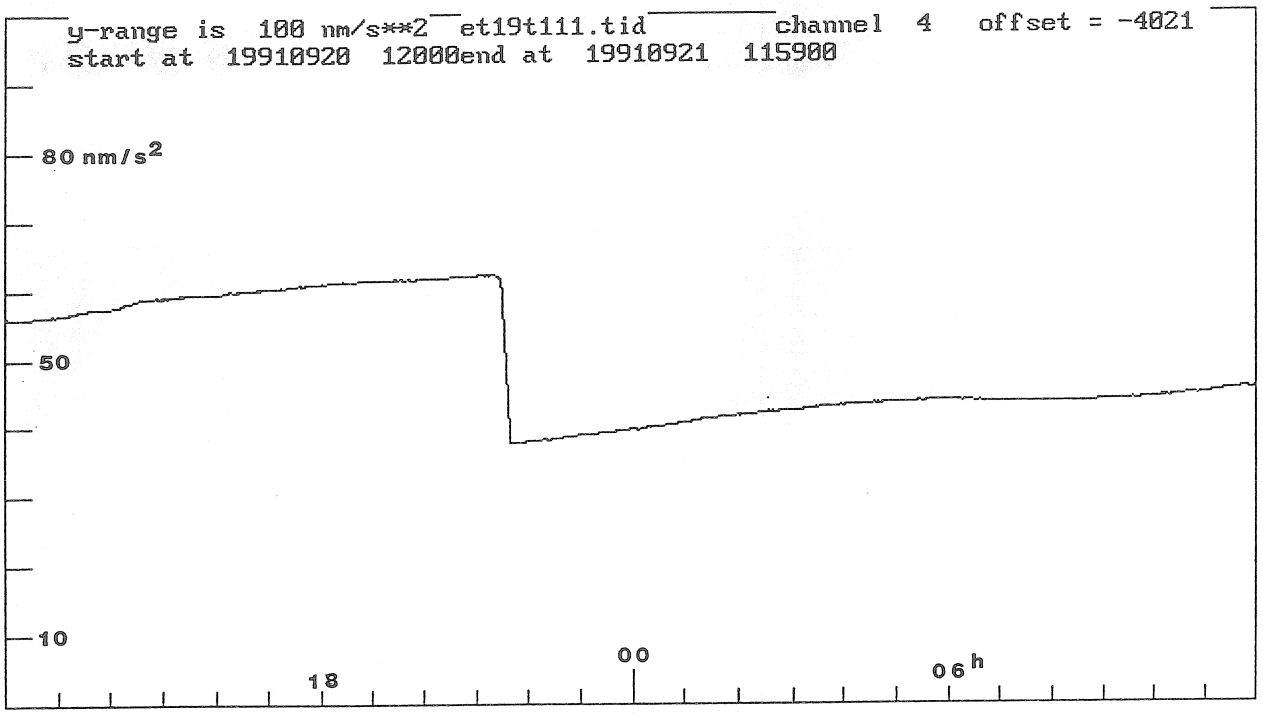

Figure 7: Detided gravity at 1 min interval recorded with gravimeter LCR-ET19 at BFO Schiltach 20.09.1991 12:00 ... 21.09.1991 11:59

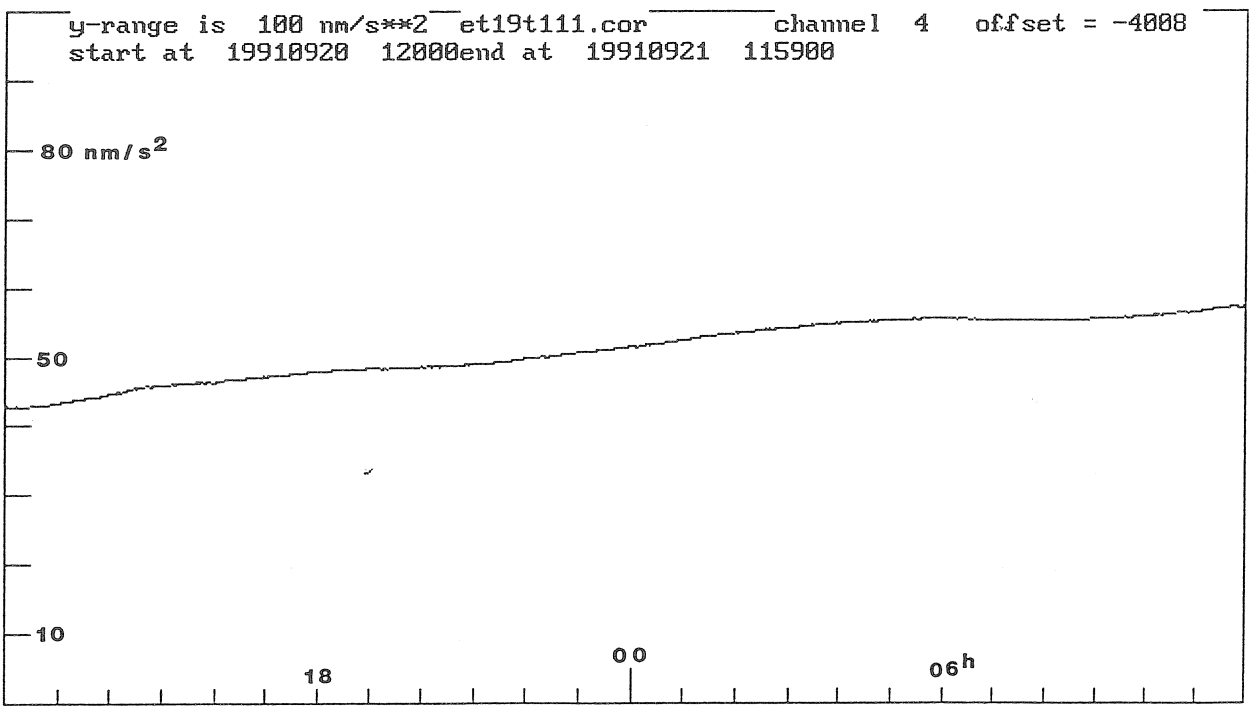

Figure 8: Detided and destepped gravity at 1 min interval recorded with gravimeter LCR-ET19 at BFO Schiltach 20.09.1991 12:00...21.09.1991 11:59

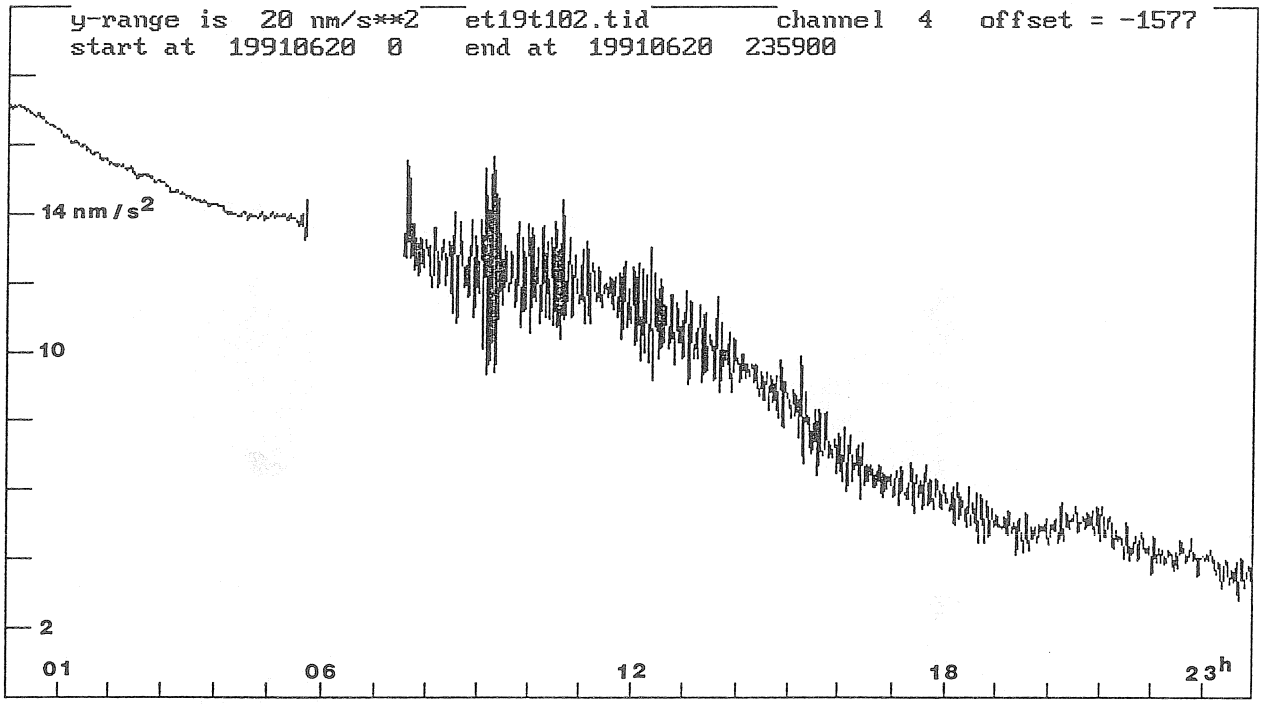

Figure 9: Detided gravity at 1 min interval recorded with gravimeter LCR-ET19 at BFO Schiltach 20.06.1991 00:00 ... 23:59. A part of the record during the arrival of surface waves has been eliminated because of feedback saturation.

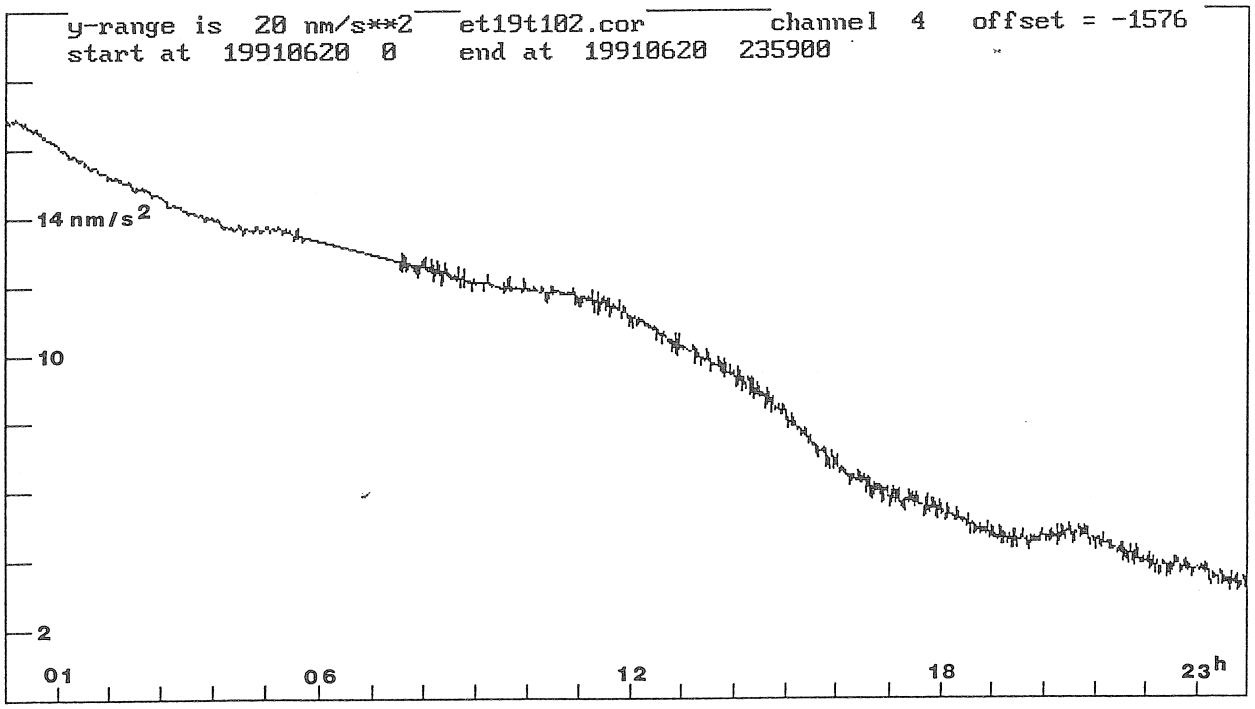

Figure 10: Despiked and degapped gravity at 1 min interval recorded with gravimeter LCR-ET19 at BFO Schiltach 20.06.1991 00:00...23:59

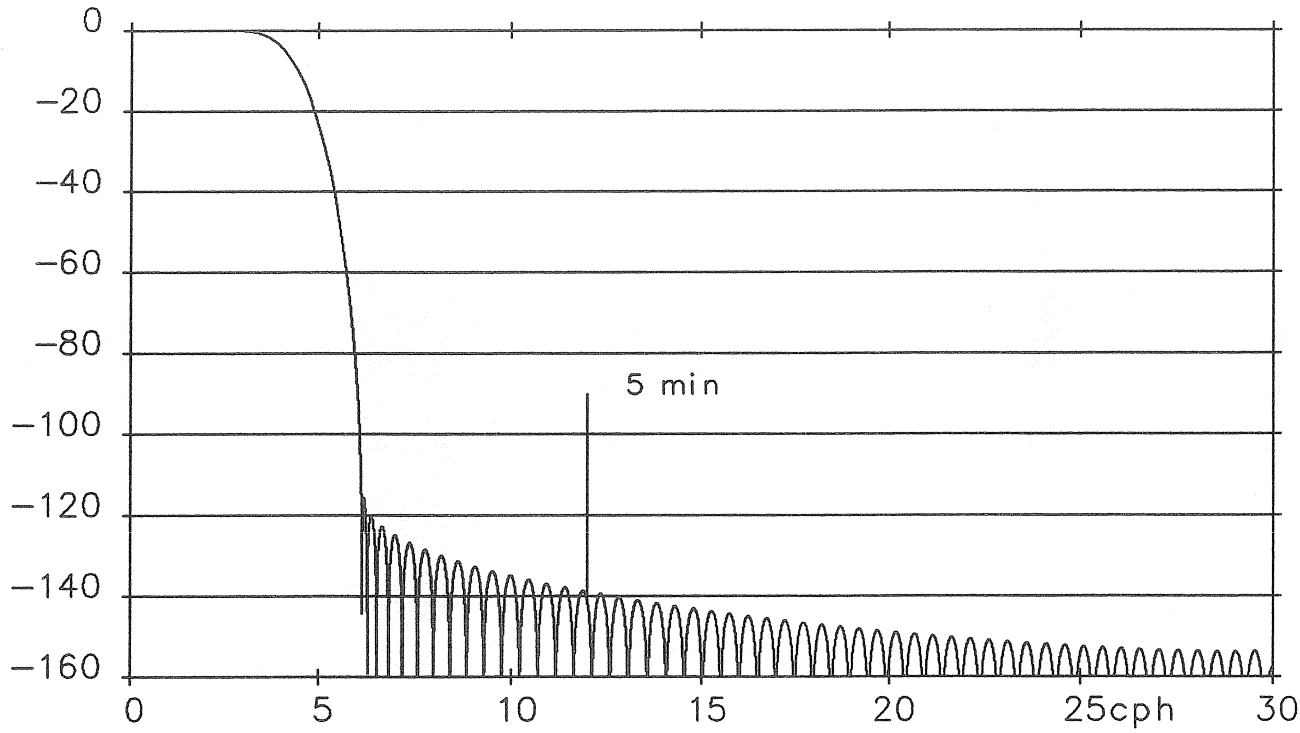

Figure 11: Amplitude gain in dB of zero phase numerical filter N2H15M, used in PRETERNA for the decimation from 1 min to 5 min resampling interval.

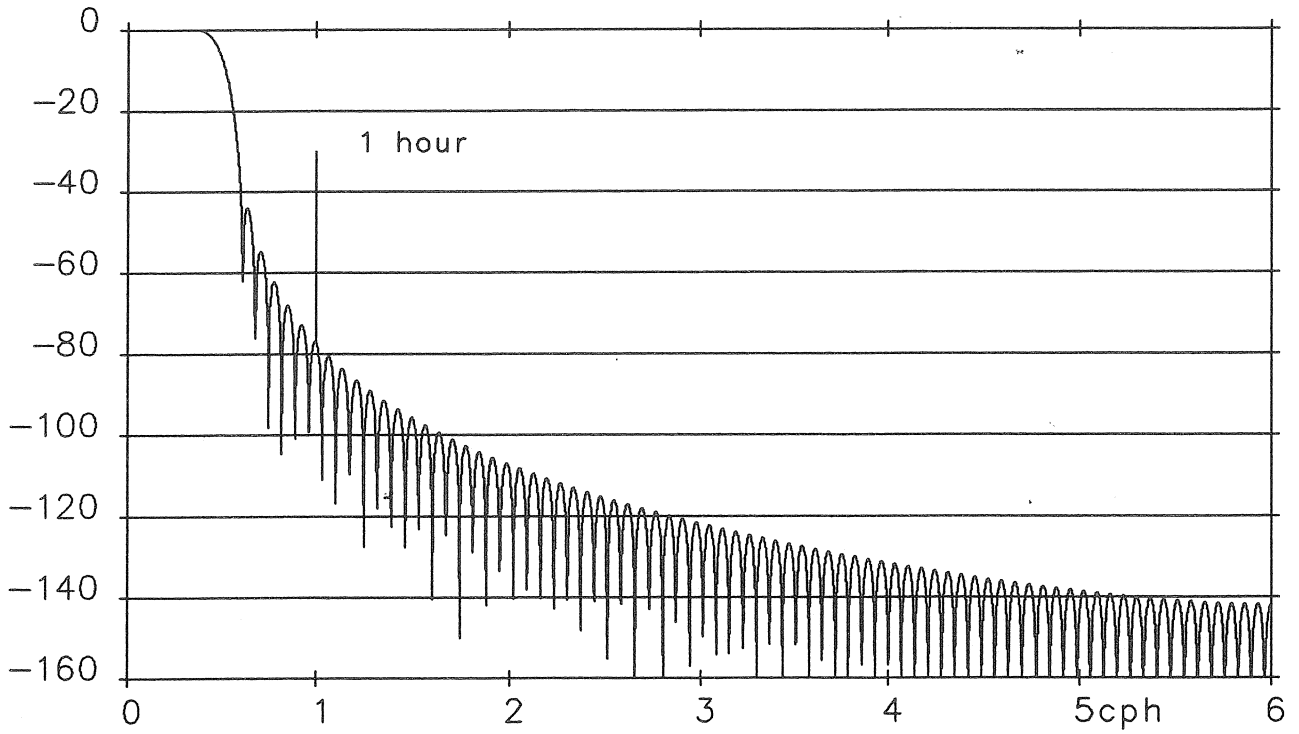

Figure 12: Amplitude gain in dB of zero phase numerical filter N14H2H, used in PRETERNA for the decimation from 5 min to 60 min resampling interval.

Degapping:

At first we look for gaps in the air pressure record and subsequently interpolate the air pressure in these gaps by a 1st degree polynomial. For the gaps in the residual signal, we use a 1st degree least squares polynomial, where samples during 10 min are used on both sides of the gap. The number of gaps is restricted to 50, and the maximum length of a gap is restricted to 48.77 h.

2.4 Computation step 4: Numerical filtering and decimation to 5 min samples

The data of channels 2 and 4 are numerically filtered using a symmetrical non-recursive FIR (zero phase) lowpass filter called N2H15M with 119 coefficients (about 2^h length) and a cutoff period of 15 min. The amplitude gain of the filter is given in Fig. 11. The time lag of the earth tide sensor and barometer is corrected within this computation step using a 2nd degree least squares polynomial over 119 samples. After filtering, the data are resampled at 5 min resampling interval and the observations are recomputed by

$$observation = residual + model\ \ tide - \alpha \cdot airpressure \tag{2}$$

Computation step 5: Numerical filtering and decimation from 5 min samples to hourly samples

The airpressure and residuals are numerically filtered using a symmetrical non-recursive FIR (zero phase) lowpass filter called N14H2H with 169 coefficients (about 14^h length) and a cutoff period of about 2^h. The amplitude gain of the filter is given in Fig. 12. After filtering, the data are resampled at 1^h resampling interval and the observations are recomputed using (2).

3 Conclusions

An automated high quality preprocessing of tidal data recorded with high rate may be carried out using the data preprocessing package PRETERNA. This package has been written and tested on IBM-AT compatible personal computers under operation systems MS-DOS and MS-WINDOWS. The main program also has been tested on a SUN SPARC2 under UNIX operation system and has achieved the same results. With PRETERNA, all computation steps can be checked by visualization of the data and results using the color screen of the personal computer. The package is well documented with a program manual and sample files and is available on request from the author.

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Observatory Schiltach). H.-J. Dittfeld and L. Timmen were so kind to test the PRETERNA package during about one year. P. Varga has stimulated the implementation of strain tides into the programs and W. Zürn has helped me in the implementation of strain tides into the programs. All this is gratefully acknowledged.

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ACCURATE INSTRUMENTAL PHASE LAG DETERMINATION FOR FEEDBACK GRAVIMETERS

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Abstract

Phase differences between observed and computed model earth tides could help to verify the rheology of the earth (pure elastic or visco-elastic mantle), if one could achieve an accuracy much better than $\pm 0.02^0$ for the phase differences. The main limitations of these phase differences in accuracy are currently due to random observational noise, systematic errors of oceanic gravitation and loading corrections and errors of instrumental phase lag corrections.

The accuracy of instrumental phase lag determinations for modern feedback gravimeters using the step response method has been found to be about $\pm 0.05^0$ at wave M2 corresponding to about ± 5 s, beeing mainly limited by inaccurate timing of manually generated steps from micrometer screw turns. By using a parallel summation amplifier (adder) in the feedback loop of gravimeter LCR-G299 with electromagnetic feedback, as well as computer controlled electronic step generation and step response digitization, the accuracy of the instrumental phase lag determination could be increased to $\pm 0.00003^0$ at wave M2 corresponding to ± 0.004 s. The instrumental phase lag determination from step response analysis has been verified to this accuracy level by input of electronically generated sine-waves into the adder and simultaneous recording of the input sine-wave and of the feedback output. This method gave a non-significant difference to the step response result of 0.00007^0 at wave M2 corresponding to 0.009 s.

1 Introduction

Recent global earth models based on seismic and free oscillation data predict 0 ... 0.02^0 phase lag corresponding to about 0 ... 2 second time lag for tidal waves at the earth's surface (e.g. WAHR 1981, DEHANT 1987, DEHANT and ZSCHAU 1989). In principle, phases from earth tide observations could help to verify the global earth models or to constrain the adjustment of these models, provided the phases of earth tide observations corrected for ocean gravitation and loading are as accurate as about 0.002^0.

The systematic errors in tidal tilt and strain observations due to e.g. cavity effects do not allow to use these data for the above described purpose. Tidal gravity observations may

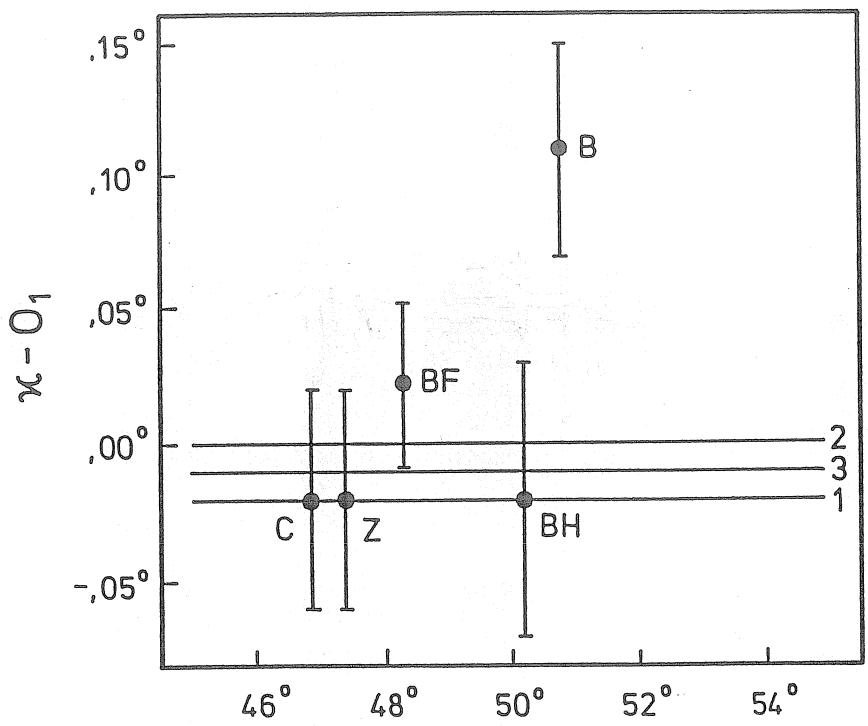

Figure 1: Phases for O1 as a function of latitude for selected European stations (WENZEL, ZÜRN and BAKER 1991). C = Chur, Z = Zürich, BF = BFO Schiltach, BH = Bad Homburg, B = Bruxelles. Solid lines represent earth models : 1 = DEHANT 1987, inelastic, 2 = DEHANT and ZSCHAU 1989, elastic, 3 = DEHANT and ZSCHAU 1989, inelastic.

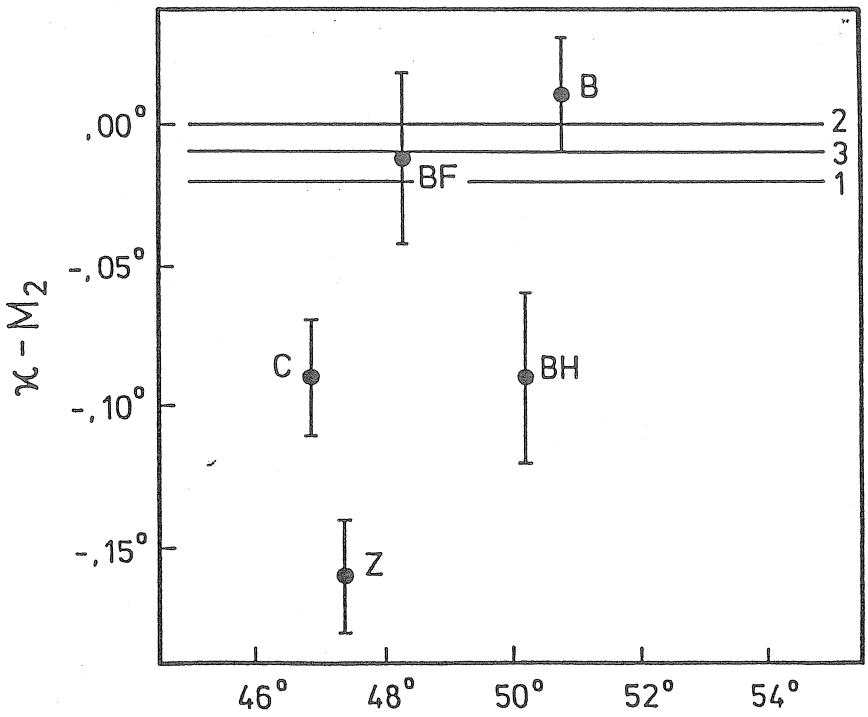

Figure 2: Same as Fig.1 for M2.

in principle be used, because their precision is generally much higher and no significant systematic errors due to environmental effects are known in the short periodic tidal band (1 to 4 cpd). In Fig. 1 and Fig. 2 taken from WENZEL, ZÜRN and BAKER 1991 the ocean corrected phases for O1 and M2 at selected European tidal gravity stations are compared with the predicted values from some recent global earth models. Although the scatter of the phases is about 0.05^0 only and the agreement with the earth models is generally good, the currently available accuracy is not sufficient to prefer one of the global earth models.

In Fig. 3 a block diagram for the determination of ocean corrected earth tide phases is given; errors in phase may be produced by a number of components in the chain from the instrument to the ocean corrected tidal phases. With modern digital recording systems a timing accuracy (sampling time with respect to coordinated universal time UTC) much better than 1 second can easily be achieved. The numerical filtering used in data recording, data preprocessing and data analysis should not give any contribution to the phase, because symmetrical zero phase filters are generally used there. The recent tidal potential developments (e.g. TAMURA 1987, XI 1989) have been checked by different authors and the phases of the main tidal waves are as accurate as about $0.002^0 \cdots 0.003^0$ (e.g. WENZEL 1994a). The precision of the adjusted phases for the main tidal waves from tidal analysis of precise gravity meter records is about 0.01^0 or less even for short records (some month's length). But the unavoidable instrumental phase lag of the observation system (gravity meter, analog and or numerical filter, recording system) is often not known to that accuracy.

We assume that the errors of the currently available ocean tide models contribute the major part to the errors of the ocean corrected tidal phases, but a significant contribution may also arise from errors in the instrumental phase lag correction. To demonstrate the significant influence of the errors of instrumental phase lag determination, we give ocean corrected phase leads for waves O1, K1 and M2 in Tab. 1, derived from records of a number of different gravimeters obtained at BFO Schiltach ($\phi = 48.3306^0$, $\lambda = 8.3300^0$). Some of these data sets have been described by WENZEL et al. 1991 and REHREN 1992. All these data sets have been obtained by digital recording and have been analyzed using the earth tide analysis package ETERNA (e.g. WENZEL 1994b). The instrumental phase lag has been determined for all records from step response experiments (e.g. RICHTER and WENZEL 1991) using hand made steps and low resolution (partly analog) recording of the step response. The instrumental phase lag has been corrected either during the preprocessing of the data or during the earth tide analysis. The ocean correction has been computed using program LOADF (AGNEW 1991) with SCHIDERSKY's 1980 global ocean tide model and is of course constant for all records. We see a rather stable and precise phase at O1 with a standard deviation of 0.022^0, but a much larger scatter of the phase lead at M2 with a standard deviation of 0.053^0, although the internal precision estimation from the tidal analysis is generally half of that for O1 and in the order of 0.01^0. A time variability of the ocean correction for M2 to that magnitude can be excluded, because the internal scatter of the phase leads obtained with gravimeter LCR-ET19 is in the order of 0.003^0 only. Thus one may conclude that the currently applied method for the instrumental phase lag determination has an accuracy of about 0.05^0 at M2 only, much worse than estimated by RICHTER and WENZEL 1991. The aim of the here presented paper is therefore to improve the methods for instrumental phase lag determination.

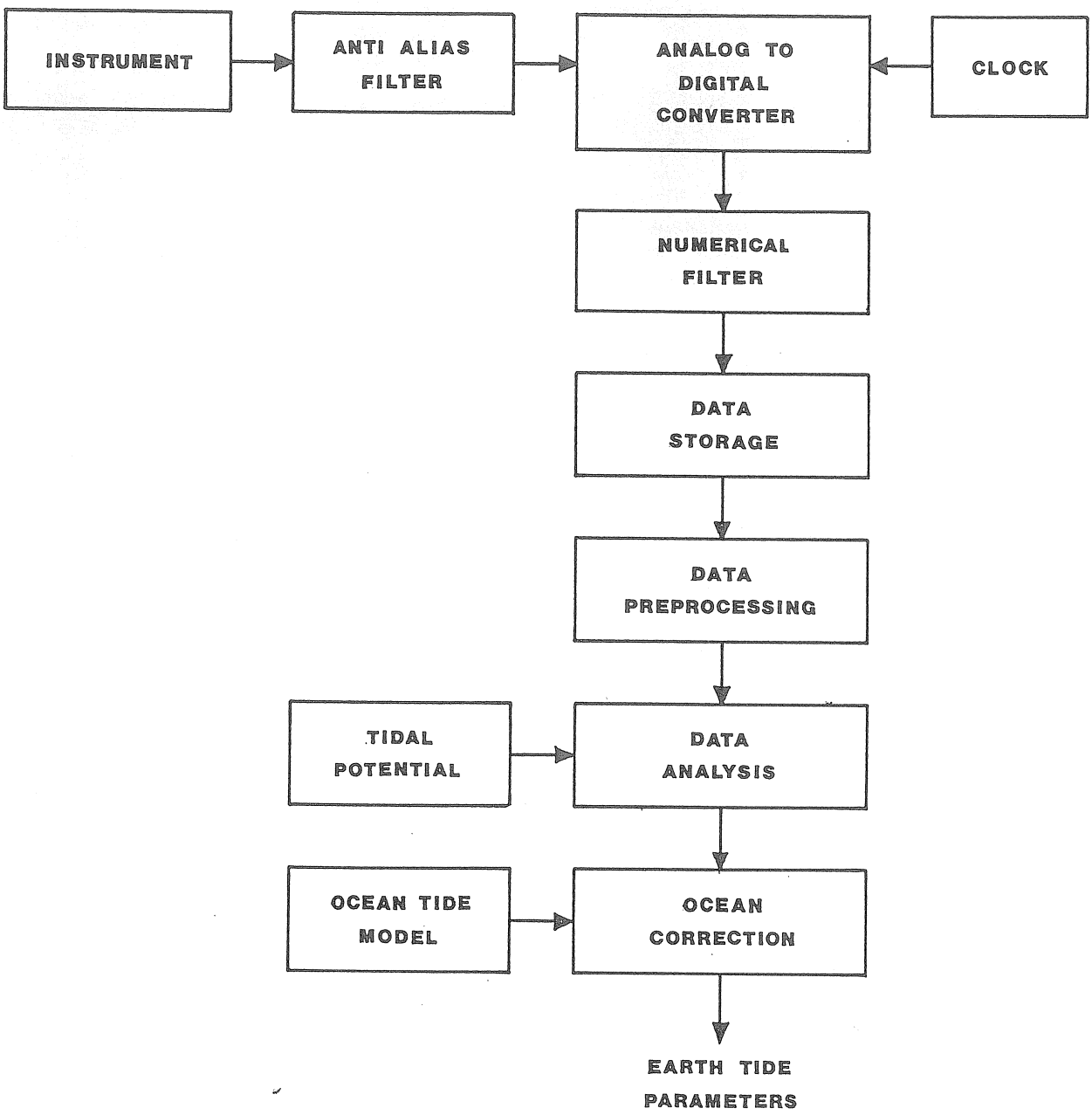

Figure 3: Block diagram for the determination of ocean corrected tidal phases.

Table 1: Ocean corrected phase leads for station BFO Schiltach

gravimeter	epoch	span [d]	phase lead O1 [^{0}]	phase lead K1 [^{0}]	phase lead M2 [^{0}]
LCR-ET19	1989	121	-0.005 ± 0.011	0.082 ± 0.008	-0.045 ± 0.008
LCR-ET19	1990	114	0.023 ± 0.011	0.063 ± 0.008	-0.048 ± 0.005
LCR-ET19	1991	286	0.026 ± 0.008	0.077 ± 0.006	-0.042 ± 0.004
LCR-G156	1989	78	0.066 ± 0.021	0.188 ± 0.015	0.090 ± 0.011
LCR-G249	1989	121	0.044 ± 0.014	0.137 ± 0.010	0.051 ± 0.008
LCR-D014	1990	166	0.033 ± 0.040	0.122 ± 0.029	-0.011 ± 0.018
LCR-G079	1990	166	0.044 ± 0.019	0.089 ± 0.013	-0.017 ± 0.010
average:			0.033 ± 0.008	0.108 ± 0.016	-0.003 ± 0.020
stdv:			± 0.022	± 0.044	± 0.053

Naturally, the limited accuracy of the ocean load corrections due to errors of the currently available ocean tide models (e.g. SCHWIDERSKY 1980) puts a severe restriction to the use of tidal gravity meters for the verification of recent global earth models. This problem will hopefully be solved in the near future by the TOPEX/POSEIDON satellite altimeter mission, especially designed for the recovery of ocean tides.

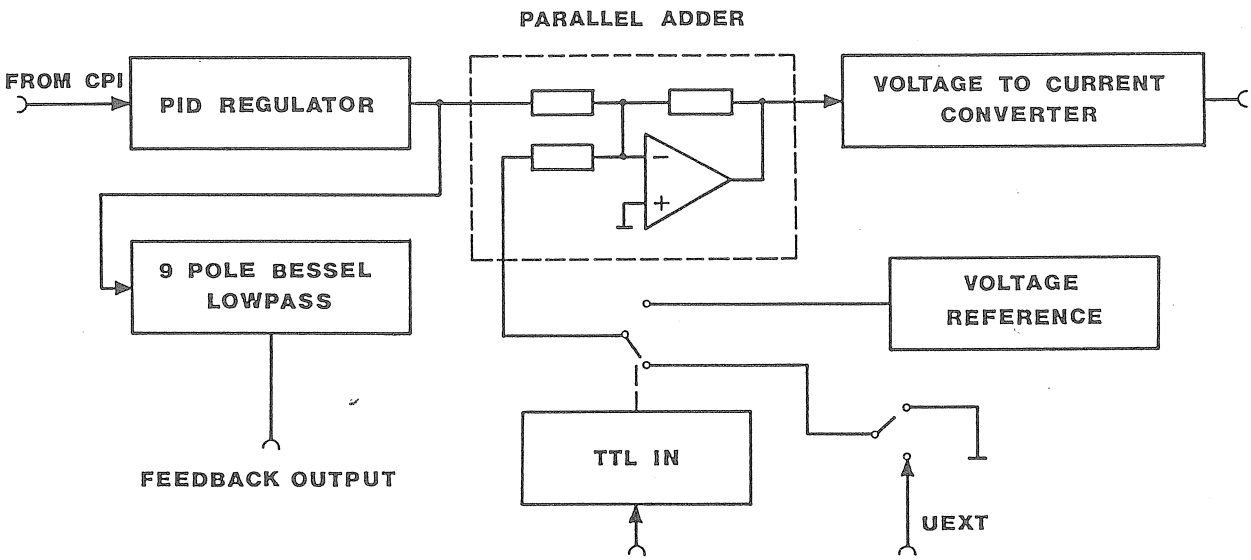

Figure 4: Electromagnetic feedback SW02 with parallel adder for gravimeter LCR-G299.

2 A parallel adder for feedback instruments

In the following we describe a parallel adder as a convenient extension for analog electrostatic or electromagnetic feedback systems. A similar device has been installed around 1980 by P. Rydelek into the electrostatic feedback of LaCoste-Romberg earth tide gravimeter ET19. The main purpose of the parallel adder is to enable an accurate determination of the instrumental phase lag of the earth tide sensor plus feedback system. Such a parallel adder is not necessarily restricted to gravimeters, but could also be applied to feedback systems for other type of sensors, as e.g. tiltmeters. A parallel adder has been implemented in the electromagnetic feedback SW02 which has been constructed recently for LaCoste and Romberg gravimeter model G no. 299, in which a small electromagnet acting on the gravimeters beam had been installed a long time ago by Dr. Brein (former at Institut für Angewandte Geodäsie, Frankfurt). A block diagram of the electromagnetic feedback SW02 is given in Fig. 4.

The feedback consists of a proportional-integral-differential (PID) regulator, the parallel adder (PAR), the voltage to current converter (VCC), a 9th order analog BESSEL lowpass filter with 30 s cutoff period, a precise 1.25 V reference voltage (UREF) and a remote controlled switch for the input of the parallel adder (TTL IN). The linear range of the feedback is about $\pm 700 \mu m/s^2$. More details of the electromagnetic feedback SW02 will be described elsewhere. The parallel adder is in fact a summing operational amplifier. The closed feedback loop will always try to regulate the input voltage of the PID to zero; thus we will have the response of the system to gravity acceleration and the parellel adder input voltage as PID output voltage.

Using the parallel adder built in LCR-G299-SW02, we may either input an external voltage or the internal reference voltage or the ground to the parallel adder. The parallel adder input is grounded in the normal operating mode for gravity tide recording. By applying + 5 V to the TTL IN terminal, the parallel adder input is switched from ground to the reference voltage, producing a step of about $65 \mu m/s^2$. By applying an external voltage UEXT (e.g. produced from a signal generator) to the parallel adder input, we apply a force proportional to UEXT to the gravimeter and the feedback tries to compensate this force and shows the response to this force at the PID output. For 1 V input to UEXT, we apply an acceleration of about $52 \mu m/s^2$ to the gravimeter.

3 The step response method

In the following, we give a short description of the step response method for the precise determination of the instrumental phase lag of earth tide observation systems. For a detailed description see RICHTER and WENZEL 1991. The method is rather general and may be applied to almost any instrument or recording system.

An ideal observation system (e.g. sensor, filter and recording system) would record the input signal $x_{(t)}$ instantaneously without any distortion :

$$y_{(t)} = x_{(t)} \tag{1}$$

with $y_{(t)}$ = output signal (observation). In fact, an ideal observation system is physically impossible, because any physical observation system needs a certain time to record the input

signal and has some small distortions (e.g. non-linearity).

In the following, we assume the observation system to be a **linear causal system with constant parameters**, i.e. the input-output relation can completely be described by

$$y_{(t)} = \int_{\tau=0}^{\infty} h_{(\tau)} \cdot x_{(t-\tau)} d\tau \tag{2}$$

with $h_{(\tau)}$ = weighting function, $\tau = t - t_0$ = time lag always greater zero ($h_{(\tau)} = 0$ for $\tau < 0$).

The model of a linear causal system with constant parameters is a good approximation for modern earth tide observation systems, e.g. spring gravity meters with a linearized feedback, analog filter and digital recording system.

The modification of the **complex spectrum** $\mathbf{X}_{(\omega)}$ of the input signal by the observation system can be described for a linear system with constant parameters by the frequency transform of (2):

$$\mathbf{Y}_{(\omega)} = \mathbf{H}_{(\omega)} \cdot \mathbf{X}_{(\omega)} \tag{3}$$

with $\mathbf{Y}_{(\omega)}$ = **complex spectrum** of the output signal, $\mathbf{H}_{(\omega)}$ = **complex frequency transfer function** of the observation system. The frequency transfer function $\mathbf{H}_{(\omega)}$ is given by

$$\mathbf{H}_{(\omega)} = \int_{\tau=0}^{\infty} h_{(\tau)} \cdot \mathrm{e}^{-\mathrm{j}\omega\tau} d\tau \ . \tag{4}$$

The complex frequency transfer function $\mathbf{H}_{(\omega)}$ can be split into it's real part $p_{(\omega)}$ and it's imaginary part $\mathbf{j} \cdot q_{(\omega)}$ by

$$\mathbf{H}_{(\omega)} = p_{(\omega)} + \mathbf{j} \cdot q_{(\omega)} \ . \tag{5}$$

An earth tide recording system usually consists of a number of different components connected in series (e.g. mechanical sensor with electronic transducer and feedback system, analog filter, digital recording system). Each of the components can be described by it's own frequency transfer function $\mathbf{H}_{\mathbf{i}_{(\omega)}}$, which usually is not known. The frequency transfer function of the complete observation system is given by the product of all individual frequency transfer functions

$$\mathbf{H}_{(\omega)} = \prod_{i=1}^{n} \mathbf{H}_{\mathbf{i}_{(\omega)}} \tag{6}$$

and only the frequency transfer function $\mathbf{H}_{(\omega)}$ of the **complete observation system** needs to be determined usually.

The frequency transfer function $\mathbf{H}_{(\omega)}$ of an earth tide observation system generally has the characteristics of a low pass filter, i.e. long periodic signals pass the observation system with only small modifications, whereas short periodic signals (i.e. with periods in the order of seconds) are heavily damped. This is mainly because of the suppression of microseismic noise due to e.g. slow feedback response or an analog low pass filter applied to the sensor signal in order to prevent aliasing.

The **amplitudes** evaluated from the recording of the observation system have to be corrected because of the **frequency dependent gain** of the observation system $G_{(\omega)}$:

$$A_{y_{(\omega)}} = G_{(\omega)} \cdot A_{x_{(\omega)}} \tag{7}$$

with

$$G_{(\omega)} = \sqrt{p^2_{(\omega)} + q^2_{(\omega)}} \tag{8}$$

and $A_{x_{(\omega)}}$ = amplitude of the input signal, $A_{y_{(\omega)}}$ = amplitude of the output signal.

It has been shown by RICHTER and WENZEL 1991, that the gain of modern gravimetric earth tide observation systems is constant over a large frequency range, usually from zero to about 0.01 cps. The determination of the system's gain for zero frequency is usually done by a calibration procedure and will not be considered in the following. The **phases** evaluated from the recording of the observation system have to be corrected because of the **frequency dependent phase lag** $\psi_{(\omega)}$ of the observation system :

$$\varphi_{y_{(\omega)}} = \varphi_{x_{(\omega)}} - \psi_{(\omega)} \tag{9}$$

with

$$\psi_{(\omega)} = \arctan \frac{q_{(\omega)}}{p_{(\omega)}} \tag{10}$$

and φ_x = phase of the input signal with respect to t = 0, φ_y = phase of the output signal with respect to t = 0. For a number of linear systems with constant parameters, the phase lag $\psi_{(\omega)}$ increases almost linear with the frequency; therefore the **phase delay time** $\theta_{(\omega)}$ (in the following simply denoted as time lag)

$$\theta_{(\omega)} = \psi_{(\omega)} \cdot T \tag{11}$$

with T = period, is almost constant for those systems over the frequency range of interest for earth tide observations.

The determination of the frequency dependent phase lag $\psi_{(\omega)}$ is the subject of this paper.

Different methods exist for the determination of the frequency transfer function of observation systems, which all apply a well known signal to the systems's input and analyse the observed system's response to the input signal. We restrict ourselves in this paper to a sine wave and a rectangular step as input signals:

- **a sine wave** with known amplitude, phase and known frequency can be supplied to the input of the observation system and the output signal of the system can be observed. By doing this for a number of different frequencies, the frequency transfer function of the observation system can be derived by comparison of the input and output amplitudes and phases (e.g. STUKENBRÖCKER 1971, DUCARME 1975). This method is implicitely applied when using an inertial platform for the calibration of earth tide gravity meters (e.g. VALLIANT 1973, RICHTER 1987, VAN RUYMBEKE 1989), although it is mainly used for the determination of the system's gain.
- **a step function** at known time can be input and the **step response** of the observation system (e.g. Fig. 6) can be observed and analysed ; this method is available for almost any earth tide instrument by using e.g. the available reset screw, an electrostatic or electromagnetic force (e.g. VOLKOV et al. 1974, WENZEL 1976, FARREL and BERGER 1979, BAKER et al. 1981, 1989, RASSON and DE MEYER 1983, 1986, RICHTER and WENZEL 1991).

The determination of the frequency transfer function from the differentiated step response described in the following does not explicitely use any parametric model of the observation system and may be applied to almost any observation system, provided it is a stable linear system with constant parameters.

If we apply a **step function** to the input of the observation system

$$x_{(t)} = \begin{cases} 0 & \text{for } t < t_0 \\ C & \text{for } t \geq t_0 \end{cases} \tag{12}$$

then (2) reads as

$$y_{(t)} = C \cdot \int_{\tau=0}^{t-t_0} h_{(\tau)} d\tau \tag{13}$$

Differentiation of (2) gives with $\tau = t - t_0$

$$\frac{dy}{dt} = \frac{dy}{d\tau} = h_{(\tau)} \cdot x_{(t-\tau)} \tag{14}$$

The weighting function $h_{(\tau)}$ is obtained by inserting (12) into (14) from

$$h_{(\tau)} = \frac{1}{C} \cdot \frac{dy}{dt} \ . \tag{15}$$

The differentiation of the recorded step response has usually to be carried out by numerical methods. The frequency transfer function $\mathbf{H}_{(\omega)}$ can be computed from the differentiated step response by FOURIER transformation, e.g. using a discrete FOURIER transformation:

$$p_{(\omega)} = \frac{1}{n} \sum_{i=1}^{n} h_{(\tau_i)} \cdot \cos \omega \tau_i \ , \tag{16}$$

$$q_{(\omega)} = \frac{1}{n} \sum_{i=1}^{n} h_{(\tau_i)} \cdot \sin \omega \tau_i \ . \tag{17}$$

Unfortunately, the step response method does not give any error estimation, because it is a pure deterministic one and not based on statistical principles. But a number of step responses may be observed and analysed and error estimates may be derived by comparison of the individual results (e.g. RICHTER and WENZEL 1991).

We have used a low rate data acquisition system called BFO-TLD1 for the generation of electronic steps and the digitization and recording of the step response of the feedback gravimeter LCR-G299-SW02 (see Fig. 5). The data acquisition system consists of a standard IBM Ps/2 model 8530 personal computer (80286/287 processor), a built-in analog to digital converter card ACPC-16-8 for 8 channels with 16 bit resolution which contains also 16 digital input/output channels with TTL level, as well as an external precise DCF77 receiver clock. This data acquisition has been used for earth tide recording at stations Karlsruhe, Postdam and Hannover. By connecting one of the digital output channels to the TTL IN terminal of the gravimeter's feedback and by connecting the feedback output to one of the analog input channels of the ACPC-16-8 card, we were able to program the PC for automatic step generation and step response recording. We generally used a step magnitude of about $65 \mu m/s^2$ and recorded the step response for 300 s = 5 min time span, generating steps every full five

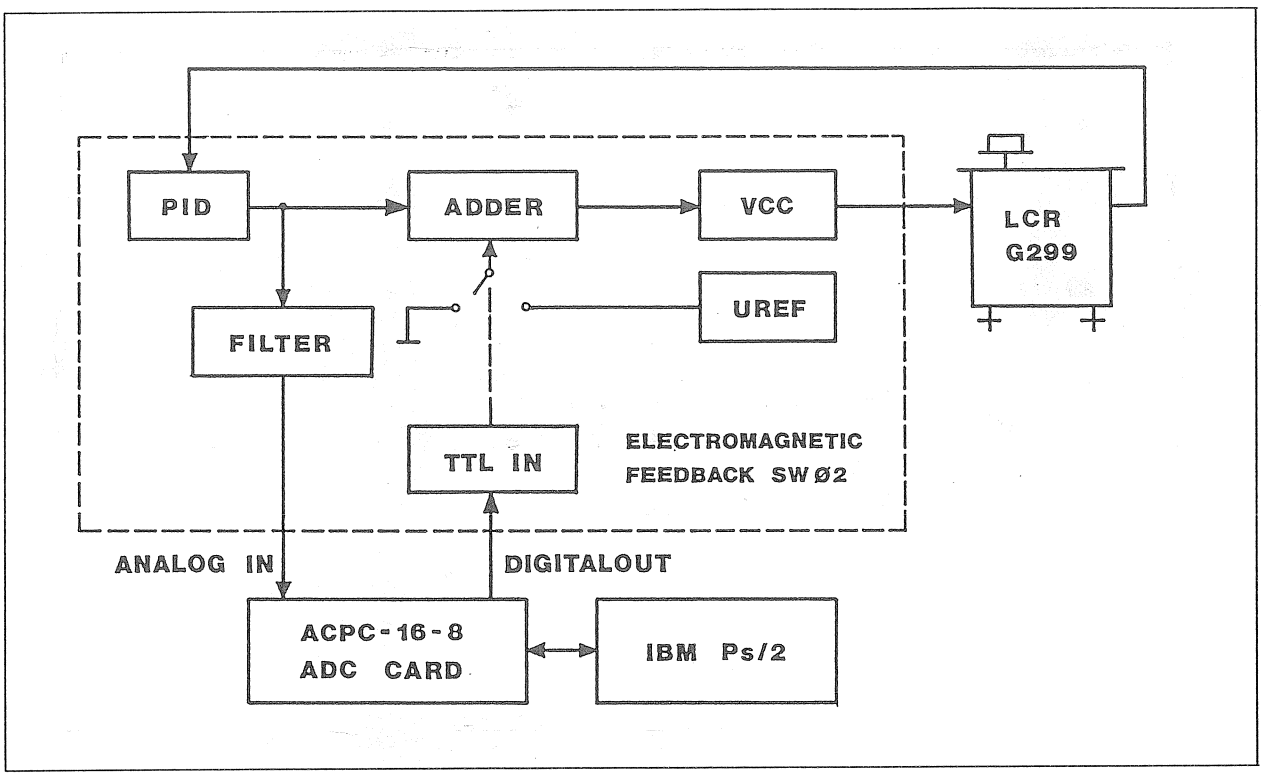

Figure 5: Setup of step response experiments with gravimeter LCR-G299-SW02 and BFO-TLD1 data acquisition.

minutes for a time interval of 2 hours. The step response was recorded at the hard disc of the PC initially with 1 sec fixed sampling interval, but later with about 0.3 sec sampling interval. We used the built-in clock of the PC to generate the step and to record the time of the digitization (in fact we used the TIMER routine available under Microsoft QuickBasic for timing purpose, with a resolution of about 0.01 s). An example for a recorded step response is given in Fig. 6.

The evaluation of the step response experiments has been done with program ETSTEP (see RICHTER and WENZEL 1991) by using a moving second degree least squares polynomial to differentiate the recorded step response. We generally used 10 successive step responses recorded within the same program run and averaged the resulting instrumental time lag and phase lag to obtain the standard deviation of the average. An example of such a run is given with Tab. 2.

Using the procedure described above, we were able to obtain a very high precision for the instrumental phase lag of about 0.0001^0 at wave M2 within a short time. We were able to determine the small influence of the long level setting of the gravimeter to the instrumental lag of about 0.04 s per level division equivalent to 0.0003^0 per level division at wave M2 (see Tab. 3), which is predicted from feedback theory but has never been observed before. But when carrying out the sine-wave input experiments described in section 4, we unfortunately found an unexplained significant discrepancy to the step response results of about 0.08 s.

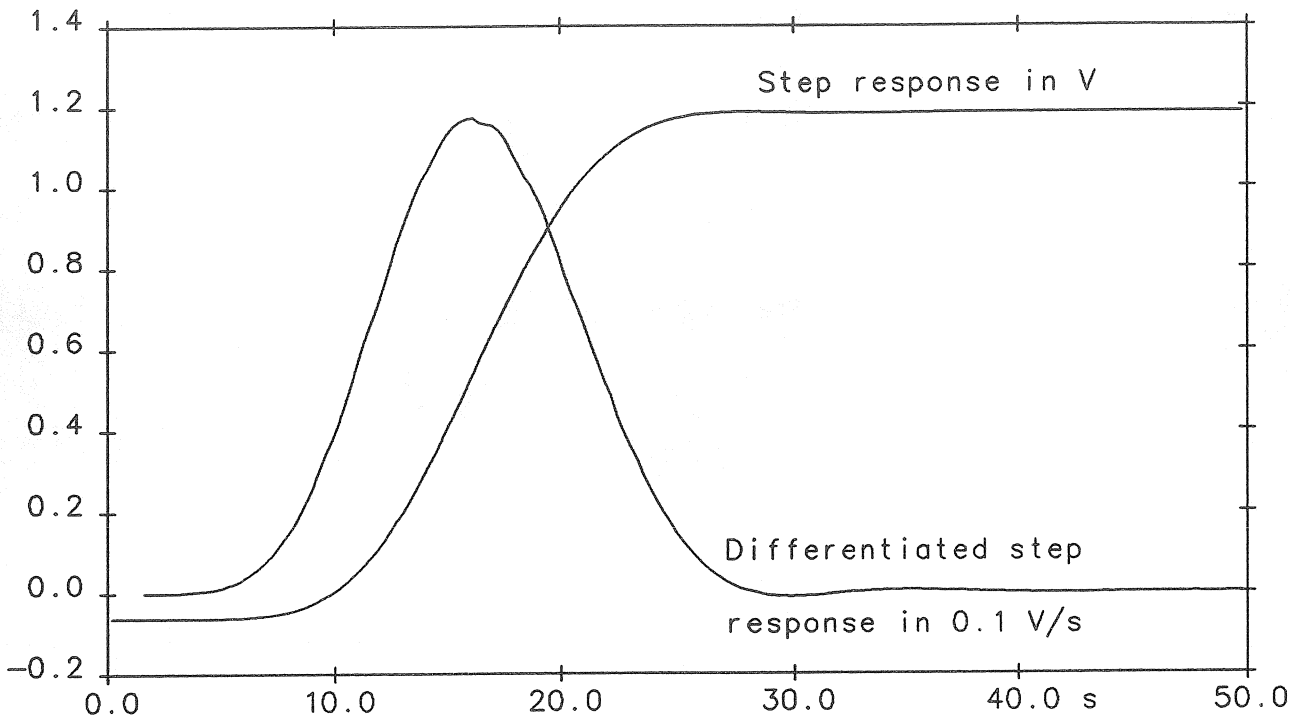

Figure 6: Step response for gravimeter LCR-G299 with electromagnetic feedback SW02, recorded 29.03.1993 at Karlsruhe, experiment ST299V80.

This discrepancy gave rise to investigate a number of different possible error sources at both methods. We finally detected a small error in the manual of the ACPC-16-8 card, yielding in a systematic timing error for the recorded step responses of 0.077 s. Although not important for other hardware setups, we describe the reason for this timing error below in order to demonstrate that one has to care for very small effects when fighting for a high accuracy in the instrumental time lag determination. The ACPC-16-8 card may be programmed to read out one analog input channel only and we had used this mode for the initial step response experiments, using analog channel 1 to record the gravimeters feedback. The conversion takes about 0.02 s for one channel. The timing of the analog to digital conversion has been obtained by calling the TIMER routine before and after calling the ACPC-16-8 routine and using the average of both TIMER values as digitization time. This procedure would have given the correct time, if the card would have read out only channel 1, but in fact the card has always digitized all eight available analog input channels independent of the card setting. This could be checked and verified by two different approaches, which are not described here. The effect due to this error was a constant time shift of 0.077 s, which has been measured and subsequently been corrected at some of the initial step response results (see Tab. 3).

The final setup for the step response experiments was to use channels 4 and 5 to record the step response, to call the TIMER routine before and after the ADC conversion routine and to use the average of channels 4 and 5 as step response and the average of the TIMER values as conversion time. The results for these final experiments are given together with some results of the initial experiments in Tab. 3.

Table 2: Instrumental time lag obtained from one step response program run

date	step time	data set	time lag [s]	phase lag at M2
29.03.1993	15:35:00 UTC	ST299V71	16.380	0.13188^0
29.03.1993	15:40:00 UTC	ST299V72	16.343	0.13158^0
29.03.1993	15:45:00 UTC	ST299V73	16.433	0.13230^0
29.03.1993	15:50:00 UTC	ST299V74	16.376	0.13184^0
29.03.1993	15:55:00 UTC	ST299V75	16.342	0.13157^0
29.03.1993	16:00:00 UTC	ST299V76	16.357	0.13169^0
29.03.1993	16:05:00 UTC	ST299V77	16.359	0.13171^0
29.03.1993	16:10:00 UTC	ST299V78	16.370	0.13180^0
29.03.1993	16:15:00 UTC	ST299V79	16.402	0.13205^0
29.03.1993	16:20:00 UTC	ST299V80	16.372	0.13181^0
average:			16.373	0.13182^0
stdv. of average:			$\pm$ 0.009	$\pm 0.00007^0$
stdv. of sample:			$\pm$ 0.028	$\pm 0.00022^0$

Table 3: Instrumental phase lag for gravimeter LCR-G299-SW02 determined from step response experiments.

date	no. of steps	long level	time lag [s]	phase lag at M2
24.11.1992	10	centered	(16.375 $\pm$0.014)	(0.13184^0 $\pm 0.00011^0$)
11.03.1993	10	centered	(16.379 $\pm$0.014)	(0.13187^0 $\pm 0.00011^0$)
11.03.1993	10	1 pars at left	(16.323 $\pm$0.022)	(0.13142^0 $\pm 0.00018^0$)
11.03.1993	10	1 pars at right	(16.404 $\pm$0.005)	(0.13207^0 $\pm 0.00004^0$)
29.03.1993	10	centered	16.364 $\pm$0.015	0.13175^0 $\pm 0.00012^0$
29.03.1993	10	centered	16.373 $\pm$0.009	0.13182^0 $\pm 0.00007^0$
average:	20	centered	16.368 $\pm$0.004	0.13178^0 ± 0.00003

note: values in brackets have been corrected for 0.077 s timing error and not been used for the average.

4 Input of a sine-wave into parallel adder

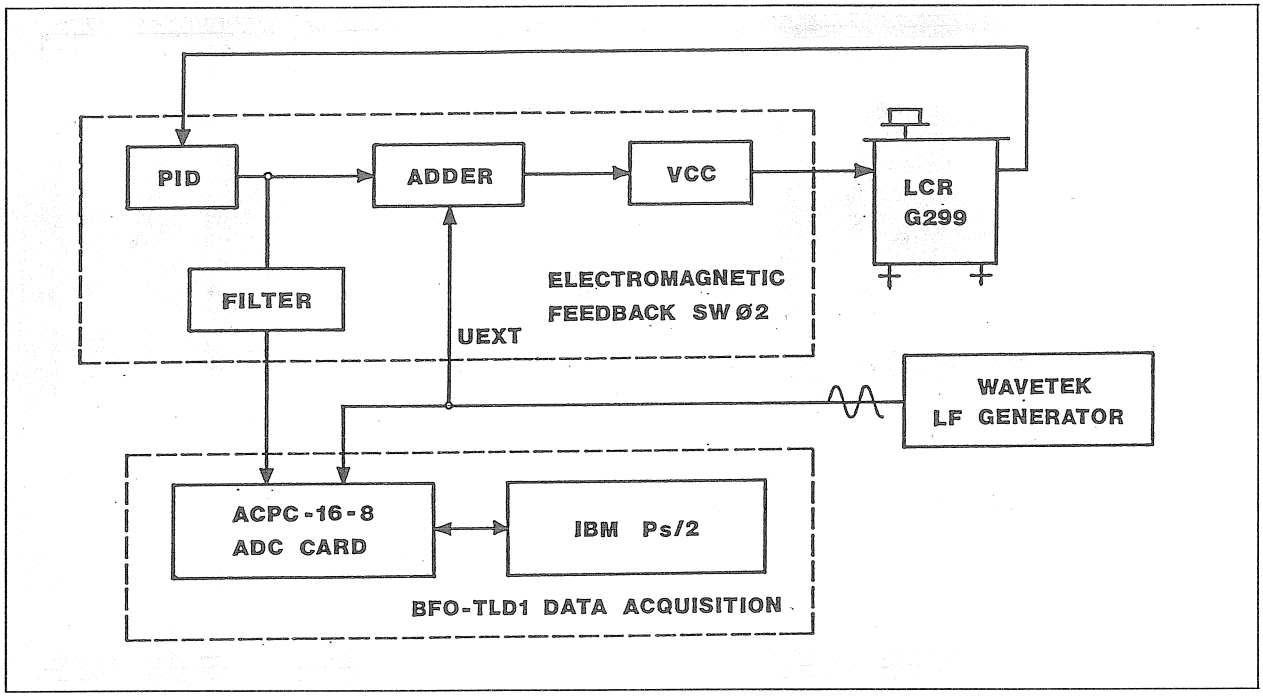

Figure 7: Setup of sine-wave experiments with gravimeter LCR-G299-SW02 and BFO-TLD1 data acquisition.

We have used the analog low frequency trigger generator model 133 of WAVETEK Inc. (0.00002 cps $\cdots$ 200 kcps) to input a sine-wave into the parallel adder and used the BFO-TLD1 data acquisition (see section 3) to record the sine wave input into the adder and the output of LCR-G299-SW02 feedback (see Fig. 7). The recording has been made with 16 bit resolution and 5 s sampling interval; the input sine-wave has been recorded at channels 1 and 3, and the feedback output has been recorded at channel 2. By using the average of channel 1 and 3 as input signal in the analysis, the delay times of the data acquisition have been eliminated. We have recorded a number of data sets by using the WAVETEK generator with different periods from 196 s to 6394 s and by recording several experiments per generator period. The recorded input and output signals with a period of 584 s are shown for a small part of a data set in Fig. 8.

The data have been analyzed by discrete FOURIER transform of both input and output signal after having applied a HANN-window to reduce leakage effects. An example of the input and output amplitude spectrum is shown in Fig. 9 and Fig. 10. We can see considerable harmonic distortions of the input and output signal at very low frequencies produced by the analog generator. But studies with simulated data have shown that the phase differences are not significantly influenced by distortions producing harmonic overtones only, when applying a HANN-window before the FOURIER transformation.

The phases of both input and output signal have been measured from the discrete FOURIER spectrum at its maximum amplitude and averaged for the data sets with constant

setting of the WAVETEK generator. The averages and standard deviations are given in Tab. 4, showing a precision of about 0.004 s for the instrumental time lag and 0.00003^0 for the instrumental phase lag at wave M2.

Table 4: Instrumental phase lag for gravimeter LCR-G299-SW02 determined from sine-wave input into adder

frequency [cph]	period [s]	time lag [s]	phase lag at M2
0.563	6394	16.355 ± 0.002	0.13168^0 $\pm 0.00002^0$
1.841	1955	16.351 ± 0.001	0.13164^0 $\pm 0.00001^0$
6.162	584	16.370 ± 0.001	0.13180^0 $\pm 0.00001^0$
18.406	196	16.359 ± 0.001	0.13171^0 $\pm 0.00001^0$
average:		16.359 ± 0.004	0.13171^0 $\pm 0.00003^0$

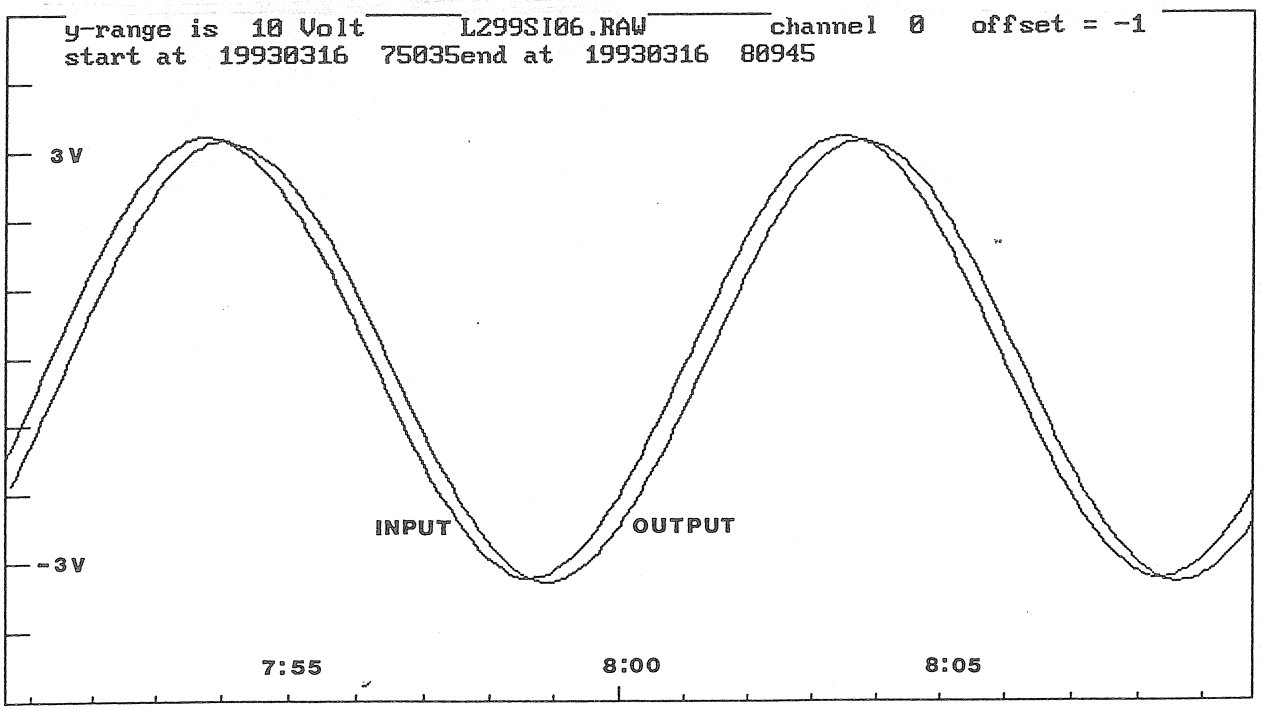

Figure 8: Zoomed part of recorded sine-wave input (left curve) into adder and feedback output (right curve) of gravimeter LCR-G299-SW02.

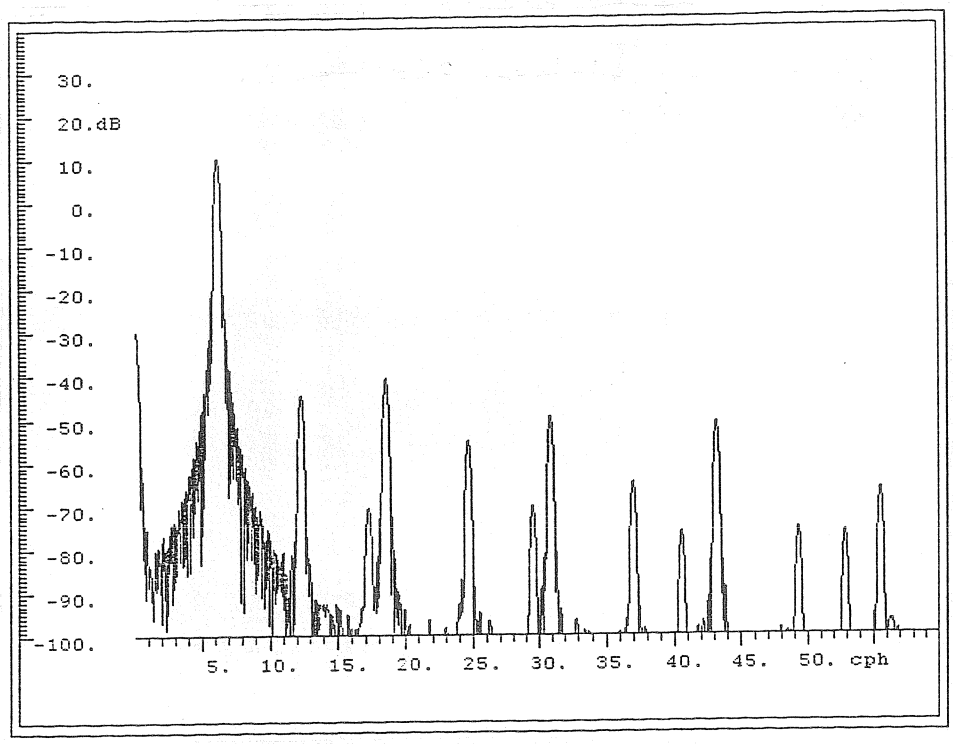

Figure 9: Spectrum of the sine-wave input into parallel adder of LCR-G299-SW02 feedback.

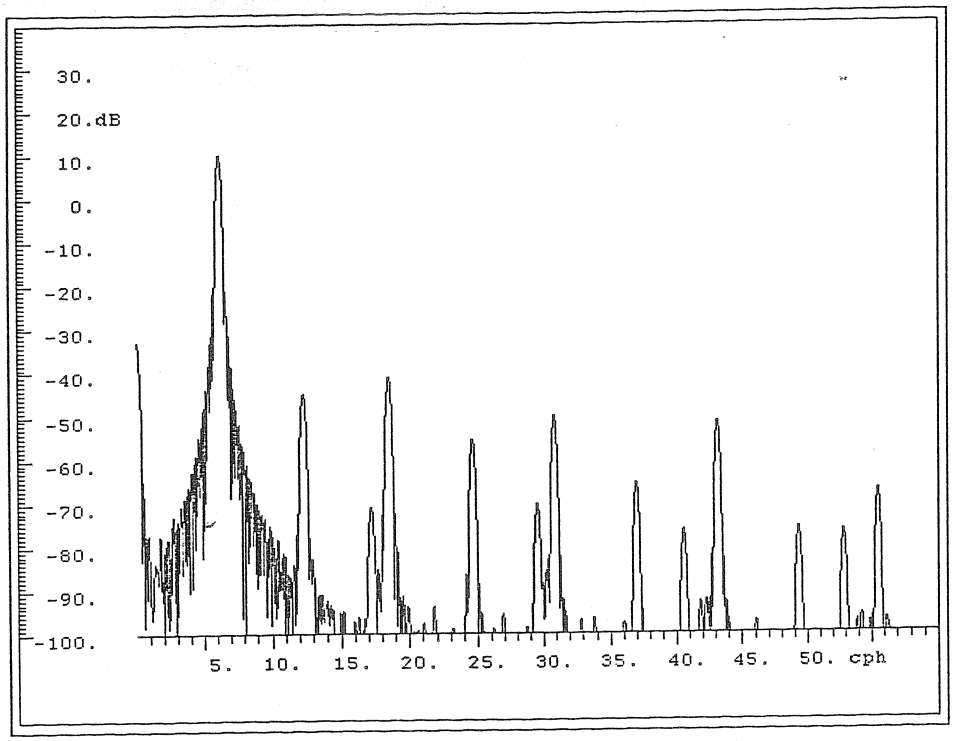

Figure 10: Spectrum of the LCR-G299-SW02 feedback output, spectrum of input signal is shown in Fig. 9.

5 Comparisons

As a third method for the determination of the instrumental phase lag of gravimeter LCR-G299-SW02 we used the measured values of the electrical components of the feedback and analog filter as well as a model of the gravimeter in non-feedback mode describing its reaction by a second order differential equation to derive the frequency transfer function of the gravimeters feedback and filter. These computations were already available from the construction of the feedback and resulted in 0.082 sec time lag of the feedback gravimeter (the feedback gravimeter has a cutoff frequency of about 2 cps because it uses a proportional-integral-differential regulator) and 16.20 s time lag of the analog filter. This results in 16.28 s total time lag with an estimated standard deviation of 0.16 s due to about 1% accuracy of the RLC-bridge used for measuring of the capacitances of the analog filter.

In Tab. 5 the results of the three independent methods applied for the determination of the instrumental phase lag of gravimeter LCR-G299-SW02 are compared. All three methods do not differ significantly from each other and all three methods are good enough for the verification of recent earth models. The step response method and the sine-wave input into adder have achieved the same standard deviation of 0.004 s equivalent to 0.00003^0 at wave M2 and the discrepancy between both methods of 0.009 s $\pm$ 0.006 s equivalent to $0.00007^0 \pm 0.00004^0$ at wave M2 is not significant. One has to mention that these discrepancies are much smaller than expected when we started these investigations and that e.g. the readout of the computers clock from the Microsoft QuickBasic program was accurate to $\pm$ 0.010 s only. Although we dont see any principal problem to further increase the accuracy of the methods which we have applied, we have not taken any action in order to increase the accuracy. This is because we believe that the achieved accuracy is already about 100 times higher than necessary for the verification of recent earth models.

Table 5: Instrumental phase lag for gravimeter LCR-G299-SW02 determined from different methods

method	time lag [s]	phase lag at M2
electric components	16.280 $\pm$ 0.160	0.13110^0 $\pm 0.00130^0$
step response	16.368 $\pm$ 0.004	0.13178^0 $\pm 0.00003^0$
sine wave	16.359 $\pm$ 0.004	0.13171^0 $\pm 0.00003^0$

6 Conclusions

A parallel adder has been found to be a very valuable extension for feedback systems. Using a parellel adder in the electromagnetic feedback SW02 for gravimeter LCR-G299 and com-

puter controlled electronic step generation and step response digitization, we were able to determine the instrumental phase lag of the gravimeters feedback at wave M2 with an accuracy of about $\pm 0.00003^0$. This is about 100 times more accurate than necessary for the verification of recent earth models and about 1000 times more accurate then currently achieved by hand made steps. We conclude that a parallel adder should be installed and used in all feedback systems used for gravimeters.

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B. Richter (Institut für Angewandte Geodäsie, Frankfurt), has kindly lend us the gravimeter LCR-G299 and P. Schott (Geodätisches Institut Karlsruhe) has constructed the electromagnetic feedback for this gravimeter. W. Torge (Institut für Erdmessung, Hannover) has given the gravimeters LCR-D014 and LCR-G079 and a data acquisition system for a parallel recording experiment at BFO Schiltach and L. Timmen and F. Rehren (Institut für Erdmessung, Hannover) have preprocessed the data sets obtained with these gravimeters at BFO Schiltach. All this is gratefully acknowledged. I am grateful to W. Zürn (BFO Schiltach), P. Schott and my daughter Christine, who were so kind to read the manuscript and to give valuable comments.

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Development of the tide generating potential with Mathematica.

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1 Introduction.

First, we have considered the Earth as a planet of which the figure is a sphere of radius a and of which the internal distribution of rheological parameters (density, compressibility, rigidity, and viscosity) presents the same symmetry of revolution. With these hypotheses, we have computed[17] a tide generating potential (TGP), named POT93, which only takes into account the direct effect of the Moon and the Sun.
Thus we did not yet consider the effect of planetary perturbations, secular variations of the arguments, nutations, Earth's flattening and other perturbations on tides, because our first aim was to make a TGP using Mathematica and to see if this software was useful to make a TGP without external perturbations. Moreover, until now nobody except Tamura[18], who considered the effects of Jupiter's opposition period and Venus' conjunction period, has considered these external perturbations.
The software Mathematica is, as we shall see, very useful and, in a future work, we will include the mentioned perturbations in order to improve POT93.
This paper deals with one aspect of the tide prediction problem, that is, the prediction of the forcing function for tides. The forcing function is here defined as the direct attraction of the Moon and the Sun. The prediction of actual tides, which includes an Earth's response, is a more difficult problem and its solution needs, among other things, an accurate prediction of the forcing function. While the tide predictions cannot yet be obtained to a much better precision level than one microgal, because of uncertainty in the ocean loading for example, or to some extent, in the free core nutation (FCN), the prediction of the forcing function to this level of precision is a necessary first step.

2 Methods to obtain a TGP.

There exist mainly two different approaches to compute an Earth tidal potential. The first one is to develop the TGP with respect to variables linearly depending on time. It is the analytical method. It was used by Doodson[7], Xi[21][22][23] and in our development[17]. We can also start from the luni-solar ephemerides, compute hourly numerical values of the tidal potential and, by harmonic analysis, identify all the terms, knowing a priori all the possible frequencies. This method, used by Cartwight-Tayler-Edden[5][6], Büllesfeld[2] and Tamura[18], is called the spectral method.

3 Presentation of the available TGP.

We can see in Table 1 the TGP that are available at the present time.

Table 1: Available tidal potentials.

Development	Year	Number of terms	Method	Potential order considering	Ephemerides	Number of signif. digits	Number of variables
Doodson1900	1921	386	analytic	Moon: 3 Sun: 2	Brown and Newcomb	5	6
CTED1900	1970	505	spectral	Moon: 3 Sun: 2	ILE[9]	5	6
Büllesfeld1900	1985	656	spectral	Moon: 4 Sun: 2	ILE	5	6
Tamura2000	1987	1200	spectral	Moon: 4 Sun: 3	JPL[1] + planetary perturbations	6	8
Xi1900	1987	1142	analytic	Moon: 3 Sun: 2	Brown and Newcomb + minor corrections	5	6
Xi2000	1987	1178	analytic	Moon: 4 Sun: 3	ILE	5	6
Xi2000	1988	3070	analytic	Moon: 4 Sun: 3	ILE	6	6
POT93	1993	3300	analytic	Moon: 4 Sun: 3	ILE	6	6

4 Development of the TGP.

The most general form of the tidal potential exerted at a point P on the Earth's surface by the Moon for example, is written as:

$$V_m^l = \frac{GM_m}{d}\left(\sum_{n=2}^{\infty} h^n P_n\left(\cos\psi\right)\right) \tag{1}$$

where P_n is the Legendre polynomial of order n and $h = \frac{c}{d}$.[1]
This expression is generally transformed into:

$$V_m^l = \underbrace{\frac{3}{4}GM_m\frac{a^2}{c^3}\left(\frac{r}{a}\right)^2}_{D(r)}\left(\frac{c}{d}\right)^3\left[\frac{4}{3}P_2 + \frac{4}{3}\frac{r}{d}P_3 + \ldots\right] \tag{2}$$

The first part of the formula is a scale factor $D(r)$, introduced by Doodson[7], depending on the geocentric distance r and the perturbing body. It can be written as:

$$D(r) = D_0\left(\frac{r}{\bar{a}}\right)^2 \tag{3}$$

where D_0 is a constant called the Doodson constant. With the presently adopted astronomical constants, its value is $2.627723\,m^2/s^2$.
For the Sun, the scale factor is noted $D_s(r)$. It can be written as:

$$D_s(r) = D_{s_0}\left(\frac{r}{\bar{a}}\right)^2 = \frac{3}{4}\frac{M_s}{M_e}\bar{g}\bar{a}^4\left(\frac{\sin\pi_s}{a}\right)^3\left(\frac{r}{\bar{a}}\right)^2 = \frac{3}{4}\frac{M_s}{M_e}G\frac{r^2}{c_s^3} = \frac{M_s}{M_m}\frac{c^3}{c_s^3}D(r) \tag{4}$$

[1] All the notations are explained at the end of this paper.

where D_{s_0} is the equivalent constant for the Sun and $\bar{g} = \frac{G}{\bar{a}^2}$.
It is desirable, however, to retain $D(r)$ as the common coefficient of both lunar and solar constituents, and to absorb the factor $\frac{D_s(r)}{D(r)} \left(= \frac{M_s c^3}{M_m c_s^3}\right)$ in the numerical coefficients of the solar constituents. This factor is called the proportionality factor and its present value is 0.45924. Note that this value is different from the Doodson's value which was 0.46040 at his time[7].
Through Laplace development, the second part will be splitted in a latitude dependent part (geodetic coefficient $g_{n,m}(\varphi)$) and a time dependent part that will generate infinite series of harmonic terms.
So the different orders of the TGP can be written as:

$$V_2 = D(r)\left(\frac{c}{d}\right)^3 (G_{2,0}H_{2,0} + G_{2,1}H_{2,1} + G_{2,2}H_{2,2}) \tag{5}$$

$$V_3 = D(r)\frac{r}{a}\left(\frac{c}{d}\right)^4 \left(\begin{array}{l} \frac{1}{3}\Gamma_{3,0}\sin\pi\, G_{3,0}H_{3,0} + \frac{1}{2}\Gamma_{3,1}\sin\pi\, G_{3,1}H_{3,1} + \\ \frac{15}{3}\Gamma_{3,2}\sin\pi\, G_{3,2}H_{3,2} + \frac{5}{6}\Gamma_{3,3}\sin\pi\, G_{3,3}H_{3,3} \end{array} \right) \tag{6}$$

$$V_4 = D(r)\left(\frac{r}{a}\right)^2\left(\frac{c}{d}\right)^5 \left(\begin{array}{l} \frac{1}{48}\Gamma_{4,0}\sin^2\pi\, G_{4,0}H_{4,0} + \frac{5}{24}\Gamma_{4,1}\sin^2\pi\, G_{4,1}H_{4,1} + \\ \frac{5}{12}\Gamma_{4,2}\sin^2\pi\, G_{4,2}H_{4,2} + \frac{35}{6}\Gamma_{4,3}\sin^2\pi\, G_{4,3}H_{4,3} + \\ \frac{35}{48}\Gamma_{4,4}\sin^2\pi\, G_{4,4}H_{4,4} \end{array} \right) \tag{7}$$

with

$$\begin{array}{ll}
G_{2,0} = \frac{1}{\Gamma_{2,0}}(1 - 3\sin^2\varphi) & H_{2,0} = \frac{2}{3} - 2\sin^2\delta \\
G_{2,1} = \frac{1}{\Gamma_{2,1}}\sin 2\varphi & H_{2,1} = \sin 2\delta\cos H = 2\sin\delta\cos\xi \\
G_{2,2} = \frac{1}{\Gamma_{2,2}}\cos^2\varphi & H_{2,2} = \cos^2\delta\cos 2H = 2\cos^2\xi - \cos^2\delta \\
G_{3,0} = \frac{1}{\Gamma_{3,0}}\sin\varphi\,(3 - 5\sin^2\varphi) & H_{3,0} = \sin\delta\,(3 - 5\sin^2\delta) \\
G_{3,1} = \frac{1}{\Gamma_{3,1}}\cos\varphi\,(1 - 5\sin^2\varphi) & H_{3,1} = \cos\delta\cos H\,(1 - 5\sin^2\delta) = \cos\xi\,(1 - 5\sin^2\delta) \\
G_{3,2} = \frac{1}{\Gamma_{3,2}}\sin\varphi\cos^2\delta & H_{3,2} = \cos^2\delta\sin\delta\cos 2H = \sin\delta\,(2\cos^2\xi - \cos^2\delta) \\
G_{3,3} = \frac{1}{\Gamma_{3,3}}\cos^3\varphi & H_{3,3} = \cos^3\delta\cos 3H = \cos\xi\,(4\cos^2\xi - 3\cos^2\delta) \\
G_{4,0} = \frac{1}{\Gamma_{4,0}}(3 - 30\sin^2\varphi + 35\sin^4\varphi) & H_{4,0} = 3 - 30\sin^2\delta + 35\sin^4\delta \\
G_{4,1} = \frac{1}{\Gamma_{4,1}}\sin 2\varphi\,(3 - 7\sin^2\varphi) & H_{4,1} = \sin 2\delta\cos H\,(3 - 7\sin^2\delta) \\
G_{4,2} = \frac{1}{\Gamma_{4,2}}\cos^2\varphi\,(1 - 7\sin^2\varphi) & H_{4,2} = \cos^2\delta\cos 2H\,(1 - 7\sin^2\delta) \\
G_{4,3} = \frac{1}{\Gamma_{4,3}}\sin\varphi\cos^3\varphi & H_{4,3} = \cos^3\delta\sin\delta\cos 3H \\
G_{4,4} = \frac{1}{\Gamma_{4,4}}\cos^4\varphi & H_{4,4} = \cos^4\delta\cos 4H
\end{array}$$

and with

$$\begin{array}{llll}
\Gamma_{2,0} = 2 & \Gamma_{2,1} = 1 & \Gamma_{2,2} = 1 & \\
\Gamma_{3,0} = \frac{2}{\sqrt{5}} & \Gamma_{3,1} = \frac{16}{3\sqrt{15}} & \Gamma_{3,2} = \frac{2}{3\sqrt{3}} & \Gamma_{3,3} = 1 \\
\Gamma_{4,0} = 8 & \Gamma_{4,1} = \frac{(3+\sqrt{393})\sqrt{390+2\sqrt{393}}}{224} & \Gamma_{4,2} = \frac{9}{7} & \Gamma_{4,3} = \frac{3\sqrt{3}}{16} \quad \Gamma_{4,4} = 1
\end{array}$$

In these expressions, the geodetic coefficients $g_{n,m}$ have been normalized into $G_{n,m}$ so that their maximum amplitudes are directly comparable. The normalization factors are noted $\Gamma_{n,m}$.
The expression of the time dependent part is not suitable for analyses of tidal phenomena because the term $\frac{c}{d}$ as well as the trigonometric functions containing δ and H exhibit very complicated time variations due to the complexity of the orbital motions of the Earth around the Sun or of the Moon around the Earth. The components of these motions must be separated carefully in order to describe the tidal potential as a sum of harmonic terms.
One particular choice of six variables which are, over an interval of a century or so, practically linearly increasing functions of time was made by Doodson:

τ time angle in lunar days;

s mean longitude of the Moon;

h mean longitude of the Sun;

p longitude of the Moon's mean perigee;

$N' = -N$ where N is the longitude of the Moon's mean node;

p_s longitude of the Sun's mean perigee.

τ can be expressed with s and h as:

$$\tau = (15°/hr)\, t + h - s - L \tag{8}$$

where t is the universal time (UT) in hours and L is the west longitude of the site.
A polynomial expression in function of time of the above arguments can be found in "The Tables of the Moon and the Sun" of Meeus[12] (1962):

$$\begin{aligned} s &= 270.43659° + 481267.89057° T + 0.00198° T^2 + 0.000002° T^3 \\ h &= 279.69668° + 36000.76892° T + 0.00030° T^2 \\ p &= 334.32956° + 4069.03403° T - 0.01032° T^2 - 0.00001° T^3 \\ N &= 259.18328° - 1 + 934.14201° T + 0.00208° T^2 + 0.000002° T^3 \\ p_s &= 281.22083°1.71902° T + 0.00045\, T^2 + 0.000003\, T^3 \end{aligned}$$

where T is the number of Julian centuries of 36525 mean solar days, measured from 1900 Jan. 1, 12 hrs.
These six variables do not yet allow to take into account the planetary perturbations. So, in a future TGP, we plan to use more variables.

5 Methods of calculation.

In order to introduce the Doodson variables in the arguments of our expansion, the second terms of the expressions for $H_{2,0} \ldots H_{3,3}$ are transformed by using:

$$\cos\delta \cos H = \cos\xi \tag{9}$$

The corresponding expressions for $H_{4,0} \ldots H_{4,4}$ are not given because there are simple relations relating them with $H_{2,0} \ldots H_{2,2}$. Note that one of the relations in Doodson's paper[7] has a factor 4 missing:

$$H_{4,4} = \text{quater-diurnal part of } \left(\frac{1}{2} 4 H_{2,2}^2\right)$$

Using some astronomical relations, we can write the following expression:

$$\begin{aligned} \sin\delta &= \sin\varepsilon \cos\beta \sin\lambda + \cos\beta \\ \cos\xi &= \cos\beta \cos\lambda \cos\chi + (\cos\varepsilon \cos\beta \sin\lambda - \sin\varepsilon \sin\beta) \sin\chi \end{aligned} \tag{10}$$

where λ, β are the true longitude and latitude of the perturbing body, ε is the inclination of the ecliptic on the equator and χ is the sidereal time which can be transformed into $(\tau + s - \frac{\pi}{2})$. So, the rest of the work consists, first, in calculating $\sin\delta$ and $\cos\xi$ from the ephemerides (λ, β) of the disturbing body, second, in computing the corresponding expressions for $H_{n,m}$, and third, in computing the expression of $(\frac{c}{d})^{n+1}$ from the given ephemeris of $\frac{c}{d}$. This work was performed with Mathematica.

6 Choice of the Ephemerides.

As we said in the introduction, no planetary perturbations or other perturbing effects were taken into account in this work. So, we have used the "Improved Lunar Ephemeris (ILE)" from Eckert, Jones and Clark[9] for the ephemeris of the Moon and we have computed manually the ephemeris of the Sun from Kepler's equation. In these ephemerides, each argument is a linear combination of the six Doodson variables.

7 Notation for the arguments.

All the calculed terms are of the forms:

$$\sum_{n=0}^{N} a_n \left\{ \begin{array}{c} \cos \\ \sin \end{array} \right\} (n_1\tau + n_2 s + n_3 h + n_4 p + n_5 N' + n_6 p_s) \tag{11}$$

So, Doodson has introduced a short method of writing such expressions, as for example:

$$2\tau - 3s + 4h + p - 2N' + 2p_s$$

The various coefficients involved in the expressions for the arguments are only occasionally outside the range -4 to 4; this suggests the use of a datum five for each in order to avoid as much as possible writing negative values. In the case of τ, however, the coefficients are always considered to be positive, and with this exception we shall get the well know argument number from Doodson:

$$229 \bullet 637$$

This number will serve to denote the argument and may also be used to denote the term as a whole.

8 Utility of Mathematica.

We believe that Mathematica is very useful for the calculation of expressions like a TGP. There are three major interests:

1. It is a software that is very easy to use and allows anybody to do such calculations without any knowledge of programming language;
2. The instruction "`Expand[expr,Trig->True]`", which is described below, is a very powerful instruction;
3. Mathematica is a professional software that many people use. So, we may hope that there are probably no programming errors.

8.1 The instruction "`Expand[expr,Trig->True]`".

As said before, to develop a TGP, we must first calculate the expressions (10) from the ephemerides of the disturbing body, then we must calculate the corresponding $H_{n,m}$, and finally calculate $\left(\frac{c}{d}\right)^{n+1}$ from the given $\frac{c}{d}$, in order to obtain the time dependent part of the TGP of

order n.
Let us take the example of the calculation of $\left(\frac{c}{d}\right)^3$ from $\frac{c}{d}$. In the ILE[9], we find:

$$\frac{c}{d} = 1 + 0.00000345\cos(h-p) - 0.00011678\cos(h-p_s) - 0.00008879\cos(2h-2p) - 0.00000251\cos(2h-2p_s) + \ldots \quad (12)$$

Thus, when we compute $\left(\frac{c}{d}\right)^3$, we must compute expressions like:

$$\cos(n_1\tau + n_2 s + \ldots)\cos(n_1'\tau + n_2' s + \ldots)\cos(n_1''\tau + n_2'' s + \ldots) \quad (13)$$

The power of Mathematica is that it is possible, with the appropriate instruction, to group such a product into a sum of functions like:

$$\cos(n_1'''\tau + n_2''' s + \ldots) \quad (14)$$

So, for example, the instruction "`Expand[`$\left(\frac{c}{d}\right)^3$`,Trig->True]`" from the given $\frac{c}{d}$ yields:

$$\left(\frac{c}{d}\right)^3 = 1.00473824 - 0.00010519\cos(2h+2N') + 0.00146653\cos(2h-2p) - 0.00004612\cos(h-p) + \ldots \quad (15)$$

9 Reading the result.

The solutions presented here have the form:

$$r_{n,m}(\tau, s, h, p, N', p_s) = \sum_{n=1}^{N} a_n \left\{ \begin{array}{c} \cos \\ \sin \end{array} \right\} (n_1\tau + n_2 s + \ldots) \quad (16)$$

$r_{n,m}$ is the m-diurnal term from the time dependent part of the TGP of order n. Each of these must be multiplied by the corresponding geodetic coefficients $G_{n,m}$ and by $D(r)$ for V_2, $\frac{r}{a}D(r)$ for V_3 and $\left(\frac{r}{a}\right)^2 D(r)$ for V_4 (because the final result depends on the coordinates of the point P where the tides are computed).

10 Comparison with other TGP.

Table 2 presents a comparison in the frequency domain, for the principal waves, between the available TGP and our potential POT93. The technical characteristics of each TGP are presented in Table 3.

10.1 Comparison between POT93 and Doodson1900.

For the lunar terms, without the contribution of the order four, the coefficients have a mean difference[2] of $1.26\,10^{-5}$ and a maximum difference of $9\,10^{-5}$. These differences may come from errors in the ephemerides, constants, calculations or more probably, from the truncation level. For all the terms, the mean difference becomes $6.5\,10^{-5}$, and the maximum difference reaches $106\,10^{-5}$ for the argument $273 \bullet 555$. This is principally due to the poor precision of the proportionality factor at that time. Indeed, if we look at the fifth column of Table 2, we see that the results corrected from the proportionality factor are now very similar.
If ones accounts for the contribution of the order four in our development, the mean difference increases to $6.98\,10^{-5}$ because Doodson has not taken it into account in his development.

[2]The mean difference is calculated from the principal waves presented in Table 2. It is not the mean difference between two complete TGP.

Table 2: Comparison of POT93 with other TGP for the principal waves.

Argument	Potential order	Moon or Sun	POT93	POT93 (prop. factor from Doodson)	POT93 (prop. factor from Xi)	Doodson 1900	CTED 1900	Xi 1900	Tamura 1900 (extrapolated)
Group 05 (of S_{s_a})									
055 • 555	2	M	50452			50458			
055 • 555	2	S	23352	23411	23351	23411			
055 • 555	4	M	4						
055 • 555	Total contribution		73808	73867	73807	73869	73806	73803	73810
055 • 565	2	M	-6553						
055 • 565	4	M	-3						
055 • 565	Total contribution		-6557			-6552	-6556	-6553	-6561
056 • 554	2	M	-16			-16			
056 • 554	2	S	1173	1176	1173	1176			
056 • 554	Total contribution		1157	1160	1157	1160	1156	1157	1157
056 • 555	3	S	1						
057 • 555	2	M	13			12			
057 • 555	2	S	7269	7287	7269	7287			
057 • 555	Total contribution		7281	7298	7281	7299	7281	7281	7281
Group 06 (of M_m)									
063 • 655	2	M	1579			1578	1579	1579	1579
065 • 455	2	M	8254			8254			
065 • 455	4	M	1						
065 • 455	Total contribution		8255			8254	8254	8254	8255
065 • 555	3	M	466			466	466	466	466
Group 07 (of M_f)									
073 • 555	2	M	1369			1370	1369	1370	1369
075 • 555	2	M	15649			15642			
075 • 555	4	M	9						
075 • 555	Total contribution		15658			15642	15647	15649	15655
075 • 565	2	M	6482			6481			
075 • 565	4	M	3						
075 • 565	Total contribution		6485			6481	6483	6481	6487
Group 08									
085 • 455	2	M	2996			2995			
085 • 455	4	M	2						
085 • 455	Total contribution		2998			2995	2996	2996	2998
085 • 465	2	M	1241			1241	1241	1241	1242
Group 12									
127 • 555	2	M	1153			1153	1152	1153	1153
Group 13 (of Q_1)									
135 • 555	3	M	-211			-211	-211	-212	-211
135 • 645	2	M	1360			1360	1360	1360	1361
135 • 655	2	M	7218			7216			
135 • 655	4	M	2						
135 • 655	Total contribution		7220			7216	7217	7218	7220
137 • 455	2	M	1371			1371	1371	1371	1371
Group 14 (of O_1)									
145 • 545	2	M	7104			7105			
145 • 545	4	M	1						
145 • 545	Total contribution		7105			7105	7106	7103	7107
145 • 555	2	M	37698			37689			
145 • 555	4	M	10						
145 • 555	Total contribution		37707			37689	37694	37698	37704
145 • 655	3	M	-108			-108	-108	-107	-108
Group 15 (of M_1)									
155 • 455	2	M	-1066			-1065	-1066	-1066	-1066
155 • 555	3	M	-660			-661	-661	-660	-660
155 • 655	2	M	-2965			-2964			
155 • 655	4	M	-1						
155 • 655	Total contribution		-2966			-2964	-2964	-2965	-2966

Argument	Potential order	Moon or Sun	POT93	POT93 (prop. factor from Doodson)	POT93 (prop. factor from Xi)	Doodson 1900	CTED 1900	Xi 1900	Tamura 1900 (extrapolated)
Group 16 (of K_1)									
162 • 556	2	M	1						
162 • 556	2	S	1027	1029	1027	1029			
162 • 556	Total contribution		1028	1030	1028	1029	1028	1029	1028
163 • 555	2	M	30			30			
163 • 555	2	S	17510	17554	17509	17554			
163 • 555	Total contribution		17540	17584	17539	17584	17543	17539	17539
164 • 555	3	S	-1						
165 • 545	2	M	1051			1050			
165 • 545	4	M	1						
165 • 545	Total contribution		1052			1050	1051	1051	1051
165 • 555	2	M	-36241			-36233			
165 • 555	4	M	-9						
165 • 555	2	S	-16774	-16817	-16774	-16817			
165 • 555	Total contribution		-53024	-53067	-53024	-53050	-53011	-53015	-53019
165 • 565	2	M	-7182			-7182			
165 • 565	4	M	-1						
165 • 565	Total contribution		-7183			-7182	-7186	-7182	-7188
Group 17 (of J_1)									
175 • 455	2	M	-2965			-2964			
175 • 455	4	M	-1						
175 • 455	Total contribution		-2966			-2964	-2964	-2965	-2966
175 • 455	3	M	-242			-241	-242	-241	-241
Group 18 (of O_{O_1})									
185 • 555	2	M	-1624			-1623			
185 • 555	4	M	-2						
185 • 555	Total contribution		-1626			-1623	-1624	-1624	-1626
185 • 565	2	M	-1039			-1039			
185 • 565	4	M	-1						
185 • 565	Total contribution		-1040			-1039	-1039	-1039	-1041
Group 23 (of $2N_2$)									
235 • 655	3	M	-156			-156	-156	-156	-156
235 • 755	2	M	2301			2301	2301	2301	2301
237 • 555	2	M	2776			2777	2776	2777	2777
Group 24 (of N_2)									
245 • 555	3	M	-569			-569	-569	-570	-569
245 • 655	2	M	17386			17387			
245 • 655	4	M	2						
245 • 655	Total contribution		17388			17387	17386	17386	17388
247 • 455	2	M	3302			3303	3302	3303	3303
Group 25 (of M_2)									
255 • 545	2	M	-3387			-3386			
255 • 545	4	M	-2						
255 • 545	Total contribution		-3388			-3386	-3390	-3387	-3392
255 • 555	2	M	90808			90812			
255 • 555	4	M	6						
255 • 545	Total contribution		90815			90812	90809	90808	90816
Group 26 (of L_2)									
265 • 455	2	M	-2567			-2567	-2567	-2568	-2567
265 • 555	3	M	525			525	525	525	525

Argument	Potential order	Moon or Sun	POT93	POT93 (prop. factor from Doodson)	POT93 (prop. factor from Xi)	Doodson 1900	CTED 1900	Xi 1900	Tamura 1900 (extrapolated)
Group 27 (of S_2)									
272 • 555	3	S	-1						-1
272 • 556	2	M	3						
272 • 556	2	S	2473	2479	2473	2479			
272 • 556	Total contribution		2476	2482	2476	2479	2476	2476	2476
273 • 555	2	M	73			72			
273 • 555	2	S	42179	42286	42178	42286			
273 • 555	Total contribution		42252	42259	42251	42358	42248	42249	42250
274 • 555	3	S	1						
275 • 555	2	M	7861			7858			
275 • 555	4	M	4						
275 • 555	2	S	3639	3648	3638	3648			
275 • 555	Total contribution		11504	11513	11503	11506	11498	11499	11502
275 • 565	2	M	3424			3423			
275 • 565	4	M	2						
275 • 565	Total contribution		3426			3423	3426	3424	3428
Group 34									
345 • 555	4	M	9						9
345 • 655	3	M	-326			-326	-326	-326	-326
Group 35									
355 • 555	3	M	-1188			-1188	-1188	-1188	-1188
Group 36									
365 • 555	4	M	-8						-8
Group 37									
375 • 555	3	M	-155			-155	-155	-155	-155
Group 38									
382 • 555	3	S	-1						-1
Group 44									
445 • 655	4	M	6						6
Group 44									
455 • 555	4	M	16						16

The coefficients are those which are used in the expression (16).
All the coefficients are given with a five digit accuracy.
In order to make this table, we have retained the terms greater than:

- 10^{-2} for the order 2 of the lunar potential;
- 10^{-3} for the order 3 of the lunar potential;
- 10^{-4} for the order 4 of the lunar potential;
- 10^{-2} for the order 2 of the solar potential;
- 10^{-5} for the order 3 of the solar potential;

The terms of order four which have a correspondent in the order two were also included.

Table 3: Technical characteristics of the different TGP.

TGP	Ephemerides	$\sin\pi$	Proportionality factor	Number of terms	Order considered
Doodson1900	Brown and Newcomb	3422.70"	0.46040	386	Moon: 3 Sun: 2
CTED1900	ILE[9]	3422.451"	0.45923	505	Moon: 3 Sun: 2
Xi1900	Brown and Newcomb + minor corrections	3422.70"	0.45923	1142	Moon: 3 Sun: 2
Tamura1900 (extrapolated)	JPL[1]	3422.448"	?	1200	Moon: 4 Sun: 3
POT93	ILE	3422.451"	0.45924	3300	Moon: 4 Sun: 3

10.2 Comparison between POT93 and CTED1900.

With the exception of the fourth order of the TGP, the mean difference is reduced to $0.85\,10^{-5}$ and the maximum difference to $4\,10^{-5}$. Because ephemerides and constants are the same as ours, only the truncation level and the developement method can explain these differences.
The mean and maximum differences increase to $1.79\,10^{-5}$ and $13\,10^{-5}$, if we consider the order four of POT93, as expected.

10.3 Comparison between POT93 and the Xi1900.

The Xi coefficients are the closest to our coefficients with a mean difference of $0.33\,10^{-5}$ and a maximum difference of $3\,10^{-5}$ (without considering the fourth order of the potential). This similarity is very important because Xi uses different ephemerides and different constants with respect to us (see Table 3). So, that similarity is certainly due to a better truncation level than the above developments and the use of the same development method.
The mean and the maximum differences increase to $1.3\,10^{-5}$ and $9\,10^{-5}$ respectively, if we consider the order four of POT93.

10.4 Comparison between POT93 and the Tamura1900.

There is a mean difference of $0.81\,10^{-5}$ and a maximum difference of $5\,10^{-5}$ with POT93. This is more than twice the difference between Xi1900 and POT93. One could think that this is due to the non-appropriated extrapolation from the Tamura2000. But, a similar comparison between Xi2000 and Tamura2000 gives a mean difference of $0.87\,10^{-5}$ and a maximum difference of $5\,10^{-5}$. So the differences could only come from the choice of the ephemerides and of the constants, or more probably, from the methods of calculation. Indeed, in Table 4, we can notice the similarity between Xi1900 and POT93 and between Tamura1900 and CTED1900. So, this shows the importance of the method of development.

11 Conclusions.

11.1 For the results.

We see that Doodson1900 has a mean difference of $6.5\,10^{-5}$ and a maximum difference of $106\,10^{-5}$ with respect to POT93 principally due to the proportionality factor that he used for the solar terms. CTED1900 reduces the mean difference to $0.85\,10^{-5}$ and the maximum

Table 4: Effect of the development method.

Argument	Potential order	Moon or Sun	POT93	CTED1900	Xi1900	Tamura1900 (extrapolated)
055 • 565	2	M	-6553	-6556	-6553	-6557
075 • 555 (M_f)	2	M	15649	15647	15649	15647
145 • 555 (O_1)	2	M	37698	37694	37698	37694
165 • 555 ($^sK_1$)	2	M+s	-53015	-53011	-53015	-53010
165 • 565	2	M	-7182	-7186	-7182	-7187
255 • 545	2	M	-3387	-3390	-3387	-3390

Table 5: Mean and maximum difference between POT93 and other TGP.

Development	Without order 4		With order 4		Possible sources of differences
	Mean diff. (10^{-5})	Max. diff. (10^{-5})	Mean diff. (10^{-5})	Max. diff. (10^{-5})	
Doodson1900 (lunar terms)	1.26	9	2.26	18	Ephemerides, constants, calculations or more probably in the truncation level.
Doodson1900 (all terms)	6.5	106	6.98	106	Proportionality factor.
CTED1900	0.85	4	1.79	13	Truncation level and method of development.
Xi1900	0.33	3	1.71	9	Ephemerides and constants.
Tamura1900 (extrapolated)			0.81	5	Ephemerides, constants or more probably in the method of calculation.
Xi2000 - Tamura2000			0.87	5	Ephemerides, constants or more probably in the method of calculation.

difference to $4\,10^{-5}$ principally due to the increase of the number of coefficients. Xi1900 and Tamura1900 are the closest ones with respect to POT93 with a better similitude for Xi1900. The mean difference with Xi1900 is $0.33\,10^{-5}$ and the maximum difference is $3\,10^{-5}$ (without the contribution of order four of the TGP). For Tamura1900, the mean difference is $0.81\,10^{-5}$ and the maximum difference is $5\,10^{-5}$. This shows the relative importance of the development method. We can also see that future developments must at least consider the fourth order of the potential for the lunar terms and the third order for the solar terms. Indeed, maximum errors of $10\,10^{-5}$ in the lunar terms of order two and $1\,10^{-5}$ in the solar terms are added to the TGP without these contributions.
The whole discussion is summarized in Table 5.

11.2 For the utility of Mathematica.

The aim of this work was not only to produce a new TGP, but mainly to show the possibility of computing a precise TGP with a scientific software like Mathematica. Because of the good agreement between POT93 and Xi1900, we see that an accurate development is possible with Mathematica. So, in a future work, we shall try to make a more precise TGP that includes many perturbations like planetary perturbations, flattening of the Earth,... The best way to test such a development would be to compare it with a benchmark series like Wenzel[19] or Merriam[16] have done.

Notation

M_m, M_s, M_e	masses of the Moon, the Sun and the Earth, respectively.
r	geocentric distance of the observation point (P).
d	instantaneous distance to the perturbing body.
c, c_s	mean distance to the Moon and to the Sun, respectively.
G	geocentric gravitational constant.
ψ	geocentric zenithal distance of the perturbing body from P.
a	equatorial radius of the Earth.
$\bar{a}$	radius of the equivolume sphere.
$\bar{g}$	mean gravity.
$\sin\pi$, $\sin\pi_s$	sine equatorial parallax of the Moon and the Sun, respectively.
φ	geocentric latitude.
δ	declination of the perturbing body.
H	hour angle of the perturbing body.
λ	ecliptic longitude of the perturbing body.
β	ecliptic latitude of the perturbing body.
ε	obliquity of the ecliptic.
χ	sidereal time.

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Results of Earth Tide Observations obtained from the Water Tube Tiltmeter Network in China[1]

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Abstract

In this paper, the stations and instrumental conditions of the water tube tiltmeter tide stations in China are briefly described. The tidal parameters deduced from the observations of several long series computed by harmonic analysis method with ICET program, are given. Corresponding results of the similar stations from Finland, Japan and the USA, are also listed in order to compare with our results.
Key words: Water-tube meter, tilt tide, Long series observation and ICET program.

1. Introduction

Recent studies on continuous measurements of crustal deformation in China and some other countries suggested that the observations obtained from water tube tiltmeters are stable and reliable because of the great length of the instrument which can effectively diminish local effects caused by the deformation of the instrumental support. Along with the completion of the special campaign organized by the State Seismologial Bureau (SSB), which develops the earthquake prediction methods and tackles the key problems in this area since 1984, the stations and instrumental conditions of the water tube tiltmeter stations have been further improved and a series of effective technological improvement have been made. The FSQ self-recording water tube tiltmeters (constructed by scientists in the Institute of Seismology, SSB, Wuhan, China) recording tidal data, have been installed at 36 tide stations covering 18 provinces and cities (see Fig.1). Furthermore, a few stations have been equiped with an automatic calibration system. The second generation network of water tube tiltmeters built in China since 1984, benefit from better stations conditions, better equipments, higher observation precision and stronger ability for reflecting earthquake events.

It is known that the study of observations obtained with tiltmeters is one of the efficient methods to investigate the distribution of the strees-strain relation during the crustal deformation. Seismologists in China and some other countries suggested that there is some

[1]Paper translated from Chinese and published in 'Crustal Deformation and Earthquake', Vol.13, No.2, May 1993.

hope to predict the earthquake events by analysing these data. Some scientists reported in previous publications many anomaly phenomena before and after earthquake events, such as deviations of the tilt tide γ factor, a change of the vectorial ratio of the EW and the NS components and the distortion of original tidal observation curves etc (see references [1], [3], [5], [10]). Because the deformation of tilt tide gives geodynamical informations in a relative wide frequency band, it can be used to detect the tendency of the crustal movement, and the physical properties of the rock rupture inside the Earth. Therefore this method fills up the black space in the medium-range frequency between seismological and geodetical measurements and it contributes to monitor the process of precursor anomaly in forming an earthquake, to develop from medium term to short-imminent term prediction and to investigate the adjustment process of crustal deformation after an earthquake. In view of this, scientists from Finland [3], Belgium, Japan [9], America [11], Italy [10] and the Russia [8] have paid great attention to the study of the Earth tilt tide in recent decades. In order to completely develop the study of the relation between the Earth tilt tide observations and the earthquake events, it is necessary to examine the situation of tidal parameters in the Chinese tilt tide network, such as the amplitude factor γ, the phase lag $\Delta\phi$ and the precision of the observations, with which we can understand our present study level in the international background in this area.

2. Stations and Instrumental Conditions

To obtain ideal observation data, the stations conditions, the instrumental equipment and the careful operation are three important elements, none of them could be absent. For most of the water tube tiltmeter stations in China, the lithological bases consist of granite volcanic rock, gneiss and quartzose standstone which have good character, solid foundation, hard and sound rock, compact and homogeneous. There are 11 stations which are covered by more than 50 m thickness within a total 36 stations in the network. The majority of rooms are set up in channel tubes for civil air defence or military engineering, except the stations Xi Bozi and Gu Zhan which were built into special crustal deformation observation by special fund, the others have partial covering or uncovering. The general situation of the lithological characters of the station's piers and the covering thickness are listed in table 3. The covering thickness over the channel tube are under 40 m for more than one half stations and most of them are between $18 \sim 29$ m. As some measures in the using the polystyrene foamed plastic plate and cabin watertight doors which can effectively reduce the effect of the micro air current disturbance, are taken, we can register with very good quality the tilt earth tide.

As the use of the advanced technique of design, the reasonable whole structure, the convenience for the operation, the visible recording system, the central-conduct-direction-

device and the calibration system, the stability, the linear degree and the observation precision come up to a international level. Nearly 30 stations have started regularly recording since 1984 and the continuous rate of the observations reaches more than 98%. For some stations, scientists are replacing the fittings with new ones because of some troubles, and for others, it is to be considered to change the site, such as Bai Jiatan, Yi Xian, Zhang Zhou, Bai Yin. The shortest instrument's length for the EW component is locate in Taian with D=10.85 m, and the longest one for the NS component is locate in Xu Zhou with D=54.48 m.

In addition, one FSQ self-registering water tube tiltmeter has been installed successfully in the Underground Geodynamics Laboratory in Walferdange, Luxembourg.

3. Harmonic Analysis Results

By using the ICET standard program of harmonic analysis (Melchior, 1980), more than 30 long series of observation data from the FSQ water tube tiltmeter stations were computed during the period of 1990-91. The longer the observation data are, the smaller the tide amplitude factor error will obviously be. In general the error of the tidal factor for different waves obtained with data of about 100 days length is half that with a data of about 30 days length and the precision is much stable. For this reason, we choose continuous data with a length greater than 200 days in the computation, except for Hu Hehaote station. Tables 1 and 2 list the harmonic analysis results of diurnal, semidiurnal and ter-diurnal waves for Xibozi and Lanzhou stations which have the best station's conditions. For other stations, only the semidiurnal results show a high sensitive to reflect the variation of the physical property of the rock in crust and they are listed in table 3. One should note that the uncorrected results by the oceanic loading for coastal stations, such as Yinkou and Shantou etc, are also listed in table 3.

The computation results which are taken from Lohja Station in Finland, Esashi station in Japan and Pinon Flat Observatory (PFO) station in North America are also listed in tables 3, 4 and 5[2] in order to compare with our results.

The harmonic analysis results show that:

(1) Though the covering thickness of the channel tube is only 18 $\sim$ 19 m for most of the tide stations in China, first-class observation results at international level can be still obtained since taking the effective technological improvement, installing the high quality instruments and making the better management. The observing precision of γ factor and $\Delta\phi$ phase lag for 28 stations (see table 3) in China, such as Xibozi, Lanzhou, Yichang,

[2]Emter, D. et al published the M_2 wave tide analysis results obtained from a water tube meter with length of 167 m at the Black Forest Observatory (BFO) station on German Dt. Geod. komn, Reiheb: $\gamma \pm m_r$ *is* 0.7014 ± 0.0016 (EW component, length of the data is 255 days)

Huailai etc, are of the same level or better than that of Lohja, Esashi and PFO which are commonly considered as the international advanced stations.

(2) Under consideration of the observation precision, the utilization ratio of the FSQ data to be found by Nakai method in China are $99 - 100\%$ for Xibozi and Lanzhou and over 94% for other stations, except for Yunlong. However, the water tube tiltmeter data in Japan (data length 186 days), North America (data length 465 days) and Finland (data length 320 days) are only 82%, 50% and 30% respectively. We show that the long term stability of the Chinese FSQ meters is better than similar instruments of different construction.

4. Conclusions

(1) The great effectiveness and progress have been obtained since we made a series of technological improvement for the stations conditions, improved the special technique management and worked out the observing technological standard;

(2) The observation precision of the tide amplitude of γ factor and phase lag $\Delta\phi$ for most of stations in the Chinese water tube tiltmeter network, are equal or better than that of the same type advanced stations in the world;

(3) The stability of water tube tiltmeter in China is better than that of other instruments;

5. Further works

The Chinese FSQ meters network will be strengthened in renewing technology, in integrating technological standard system, in training specialized people and in achieving the modernization and intelligence level. The procedures for examining and checking the data quality will be improved in the further researches. It is hope that for the network system the capacity to reflect earthquakes, the precision of the observation data, the management level will be put into a new step in the near future.

6. Acknowledgement

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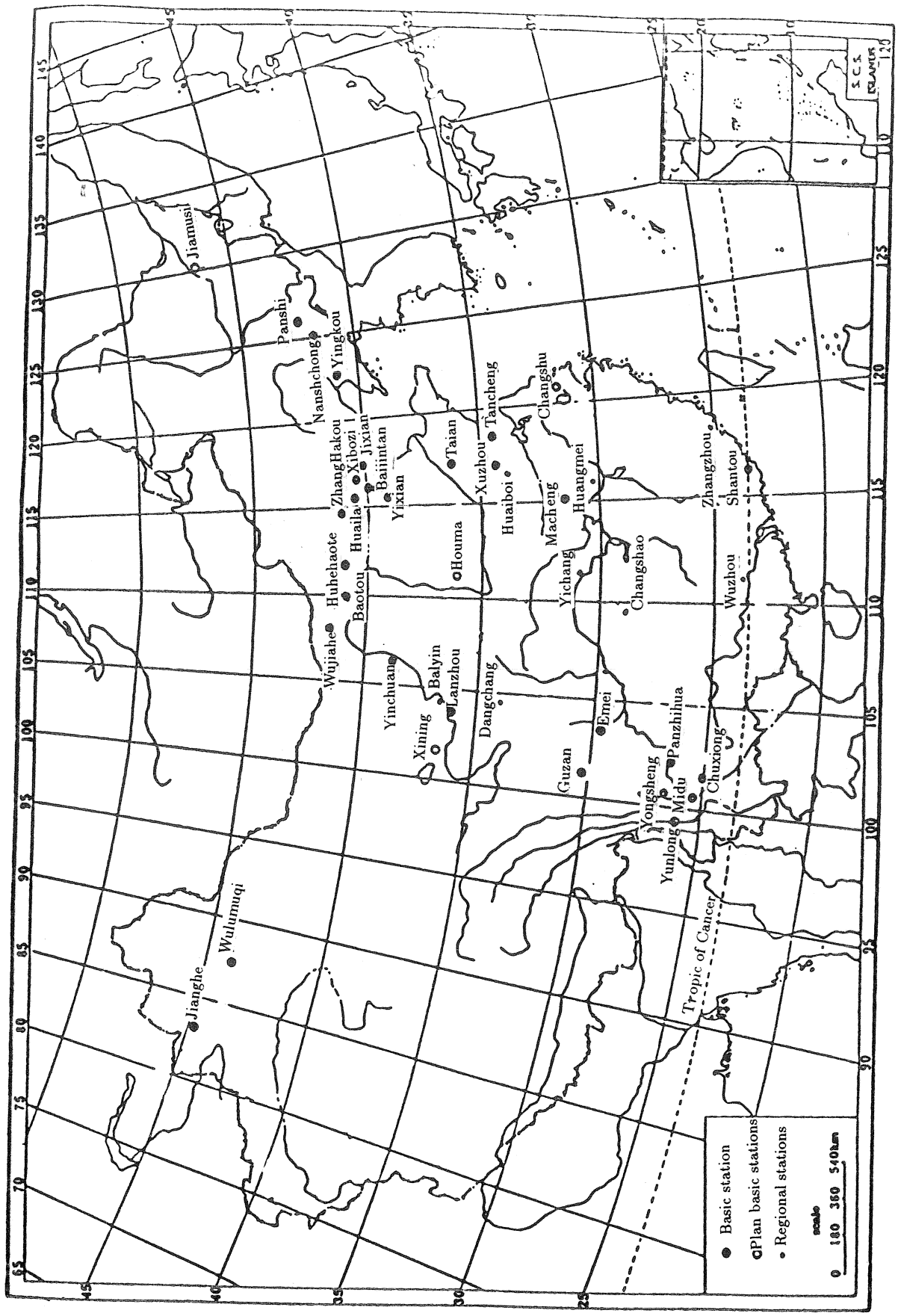

Fig. 1 Network of water-tube tiltmeters for Earth Tide observations in China

Table 1 Xibozi station, data length 730 days (1990. 1～1991. 12.), EW component

	wave	γ Factor	mean square error	phase lag	mean square error
diurnal	Q_1	0.5673	0.0204	−4.095	2.06
	O_1	0.5382	0.0039	0.073	0.41
	P_1	0.5968	0.0091	4.128	0.87
	K_1	0.6293	0.0028	5.526	0.26
	J_1	0.6352	0.0459	6.972	4.14
	OO_1	0.7145	0.0781	4.883	6.27
semidiurnal	$2N_2$	0.6422	0.0288	−2.088	2.57
	N_2	0.6329	0.0039	−2.230	0.36
	M_2	0.6102	0.0008	−1.635	0.07
	L_2	0.5489	0.0335	7.971	3.50
	S_2	0.6520	0.0016	2.694	0.14
	K_2	0.6161	0.0051	0.316	0.48
ter-diurnal	M_3	0.7164	0.0244	−4.843	1.95

Lithologic character of station piers: Andesite; Covering thickness: 98 meters.
Instrument: FSQ Type water tube tiltmeter; legnth: 33.5 meters
Utilization coefficient of data: 99 percent.

Table 2 Lanzhou station, data length 365 days, (1990. 1～12), EW component.

	wave	γ Factor	mean square error	phase lag	mean square error
diurnal	Q_1	0.6263	0.0256	6.047	2.34
	O_1	0.6594	0.0049	4.597	0.43
	P_1	0.6582	0.0118	10.112	1.03
	K_1	0.7215	0.0036	7.565	0.29
	J_1	0.7960	0.0603	5.506	4.34
	OO_1	0.5397	0.0947	17.763	10.06
semidiurnal	$2N_2$	0.6781	0.0319	5.417	2.29
	N_2	0.6664	0.0043	0.416	0.37
	M_2	0.6629	0.0009	0.241	0.07
	L_2	0.6312	0.0332	1.361	3.02
	S_2	0.6289	0.0018	5.942	0.16
	K_2	0.6723	0.0054	3.421	0.46
ter-diurnal	M_3	0.8143	0.0383	−1.175	2.69

Lithologic character of station piers: Granite; Covering thickness: 52 meters
Instrument: FSQ Type water tube tiltmeter; legnth: 44.7 meters
Utilization coefficient of data: 100 percent.

Table 3 Harmonic analysis results of semi-diurnal tide wave of water tube tiltmeter tide stations

station	lithologic character	Covering thickness Length	Oberva-tional time of data Calibration coefficient of data	γ value and its standard error M2	N2	S2	M2 wave Δφ	mean square error of phase lag M2	N2	S2	remarks
Xibozi	andesite	98 33.5	729 99	0.6102 ±0.0008	0.6329 ±0.039	0.6520 ±0.0016	-1.635	0.07	0.36	0.14	1990.1~91.12. EW,730 days
Lanzhou	granite	52 44.7	363 100	0.6629 0.0009	0.6664 0.0043	0.6289 0.0018	0.241	0.07	0.37	0.16	1990.1~12. EW,365 days
Yichang	conglomera rock	29 30.0	724 94	0.6775 0.0011	0.6741 0.0055	0.6849 0.0023	1.386	0.09	0.47	0.19	1990.1.~91.12 EW,730 days
Dargchang	sandy slais	32 30.1	364 88	0.6486 0.0011	0.6369 0.0059	0.7193 0.0024	0.241	0.10	0.54	0.19	1991.1~12. EW,365 days
Huaitai	granitic gneise	42 28.4	344 100	0.5896 0.0012	0.6201 0.0064	0.6025 0.0026	0.342	0.12	0.59	0.24	1990.1.1.~12.9. EW,344 days
Guzi	biotite diorite	88 29.7	333 99	0.6619 0.0012	0.6477 0.0065	0.6346 0.0026	18.497	0.11	0.58	0.24	1991.1.~12. EW,365 days
Changsha	quartzone sandstone	24 22.4	365 93	0.6799 0.0012	0.6752 0.0060	0.6899 0.0024	0.605	0.10	0.51	0.20	1990.1~12. EW,365 days
Tai-an	granitic gneise	24 10.8	728 94	0.6842 0.0013	0.6542 0.0075	0.6956 0.0027	3.387	0.11	0.66	0.22	1986.1.~87.12 EW,730 days
Yongsheng	quartzone sandstone	56 38.0	364 99	0.6257 0.0013	0.6182 0.0068	0.6325 0.0027	2.065	0.12	0.63	0.25	1991.1.~12. EW,365 days
Midu	basalt	25 25.0	365 98	0.6204 0.0013	0.6028 0.0070	0.6079 0.0028	5.201	0.12	0.67	0.26	1991.1.~12. NE,365 pays
Nan Shancheng	granite	42 37.6	334 99	0.5087 0.0013	0.5314 0.0069	0.6455 0.0027	1.083	0.14	0.75	0.24	1992.2.~12. NS,334 days

Ji Xian	limestone	75 39.1	364 95	0.6160 0.0014	0.6116 0.0069	0.6487 0.0028	15.684	0.13	0.65	0.24	1990.1.~12. EW,365 days
Yunlong	sandstone	60 33.8	364 85	0.6824 0.0014	0.6656 0.0074	0.6737 0.0029	-1.160	0.12	0.64	0.25	1991.1.~12. EW,365 days
Macheng	granitic gneise	25 32.6	364 98	0.963 0.0015	0.6880 0.0078	0.7055 0.0032	5.722	0.12	0.65	0.25	1990.1.~12. EW,365 days
Chuxiong	sandstone	34 35.8	365 93	0.6466 0.0015	0.6373 0.0077	0.7779 0.0030	1.575	0.13	0.69	0.22	1990.1.~12. EW,365 days
Huaibei	limestone	50 14.4	333 89	0.7132 0.0016	0.6961 0.0081	0.8416 0.0033	-7.473	0.13	0.67	0.22	1991.2.~12 EW,365 days
Wuzhou	Granite	32 25.5	214 98	0.7141 0.0016	0.7254 0.0081	0.6884 0.0034	5.220	0.13	0.64	0.28	1991.6.~12. EW,214 days
Zhangjiakou	volcanic rock	39 28.6	212 95	0.6342 0.0018	0.6389 0.0095	0.6646 0.0039	3.246	0.17	0.80	0.34	1991.1.~7 NS,212 days
Xuzhou	limestone	68 54.4	303 96	0.5783 0.0018	0.5425 0.0096	0.6721 0.0038	6.225	0.18	1.02	0.32	1991.1.~10. NS,304 days
Tan Cheng	sandstone	60 29.0	364 97	0.6878 0.0019	0.5444 0.0099	0.7073 0.0041	32.227	0.16	1.05	0.32	191.1.~12. EW,365 days
She Xian	limestone	18 27.9	274 88	0.6709 0.0019	0.6670 0.0099	0.8508 0.0044	4.804	0.16	0.85	0.30	1991.1.~12. EW,365 days
Yin Chuan	mix granite	40 30.4	364 100	0.6070 0.0019	0.5907 0.0098	0.5902 0.0040	14.309	0.18	0.93	0.39	1991.1.~12. EW,365 days
Huang mei	granite	24 17.8	334 90	0.6887 0.0020	0.6879 0.0109	0.6025 0.0043	1.994	0.17	0.90	0.41	1991.2.~12. EW,334 days
Panshi	granite	60 22.8	364 90	0.5659 0.0020	0.5901 0.0103	0.6301 0.0043	18.282	0.21	1.00	0.38	1991.1.~12. EW,365 days
Wujiahe	granite	250 27.8	184 100	0.6343 0.0020	0.6464 0.0103	0.6642 0.0043	0.778	0.18	0.91	0.36	1991.7.~11. EW,184 days
Wulumugi	sandy shale	24 30.0	183 95	0.5837 0.0024	0.5812 0.0122	0.5517 0.0051	-3.089	0.24	1.20	0.54	1991.6.11. EW,184 days

Lanzhou/railway/college/granite		86 63.6	275 100	0.4937 0.0026	0.5009 0.0133	0.4851 0.0057	-0.376	0.31	1.52	0.68	1991.4.~12. EW,275 days
Huhehaote	rhyolite	28 23.8	90 100	0.6114 0.0033	0.6558 0.0193	0.7374 0.0061	5.247	0.31	1.68	0.47	1991.9.~11. EW,90 days
Yingkou *	granite	29 30.0	364 90	1.2147 ±0.0044 (0.0025)	1.2309 ±0.0225 (0.0130)	0.7888 ±0.0092 (0.0053)	-15841	0.21	1.04	0.67	1991.1.~12. EW,365 days
Shantou *	granite	40 30.0	365 98	1.0142 ±0.0045 (0.0031)	1.1945 ±0.0233 (0.0161)	0.4576 ±0.0093 (0.0064)	-38.760	0.25	0.12	1.16	1991.1.~12. EW, 365 days
Finland	limestone	167 180.0	96 30	0.7013 ±0.0015	0.6938 ±0.0088	0.7044 ±0.0032	-2.260	0.12	0.73	0.25	1977.6.~78.4. EW,320 days
Japon	granite	60 45.0	186 82	0.4080 ±0.0012	0.4415 ±0.0063	0.3956 ±0.0027	-17.710	0.17	0.81	0.38	1979.6.~12. NS,186 days
American	granite	2 535.0	232 50	±0.0030				1.8			1984 465 days

* coastal stations: results in brackets have been corrected by oceanic effect.

Table 4 Lohja station Finland. data length 96 days(1977. 6～1978, 4), EW component.

	wave	γ Factor	mean square error	phase lag	mean square error
diurnal	Q_1	0. 6056	0. 00486	3. 73	4. 59
	O_1	0. 7101	0. 0090	−2. 39	0. 73
	M_1	1. 6171	0. 3124	−9. 71	11. 00
	$P_1S_1K_1$	0. 7249	0. 0059	−2. 98	0. 46
	J_1	0. 6168	0. 1072	5. 57	9. 97
	OO_1	0. 9195	0. 3628	21. 03	22. 52
semidiurnal	$2N_2$	0. 7384	0. 0515	4. 33	3. 94
	N_2	0. 6938	0. 0088	−2. 81	0. 73
	M_2	0. 7013	0. 0015	−2. 26	0. 12
	L_2	0. 7301	0. 0356	1. 21	2. 78
	S_2N_2	0. 7044	0. 0032	−1. 18	0. 25

Lithologic character of station piers; Limestone; Covering thickness; 167 meters.
Instrument; Long water tube tiltmeter; legnth: 180 meters
Utilization coefficient of data; 30 percent.

Table 5 Esashi station in Japan, data length 186 days(1979. 6～12), NS component

	wave	γ Factor	mean square error	phase lag	mean square error
diurnal	Q_1	1. 6456	0. 0798	12. 32	2. 78
	O_1	1. 3781	0. 0146	5. 67	0. 61
	M_1	0. 7935	0. 0731	19. 15	5. 28
	P_1	1. 1247	0. 0258	−2. 89	1. 32
	S_1K_1	1. 4495	0. 0096	−2. 40	0. 38
	J_1	0. 9720	0. 2015	−25. 09	11. 87
	OO_1	1. 2004	0. 4273	−30. 02	20. 39
semidiurnal	$2N_2$	0. 4177	0. 0313	−11. 22	4. 30
	N_2	0. 4415	0. 0063	−10. 60	0. 81
	M_2	0. 4080	0. 0012	−17. 71	0. 17
	L_2	0. 2211	0. 0413	−29. 42	10. 72
	S_2	0. 3956	0. 0027	1. 93	0. 38
	K_2	0. 3187	0. 0125	−12. 39	2. 25
ter-diurnal	M_3	0. 7549	0. 0474	−28. 53	3. 60

Lithologic character of station piers; Granite; Covering thickness; 60 meters.
Instrument; Float moving type water tube tiltmeter; legnth: 45.0 meters
Utilization coefficient of data; 82 percent.

ICET as a World Data Centre for Earth Tides.

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1994

1. The WDC System

Since the International Geophysical Year (IGY) 1957/58, the International Council of Scientific Unions (ICSU) has maintained a World Data Centre System (WDCs), which serves to collect, store, process as appropriate, and redistribute data in the solar-geophysical-related environmental scientific areas. The essential ICSU Guidelines for International Exchange of Data and the Responsibilities of the WDCs are as follows:

- ICSU-sponsored scientific programs, and ICSU-endorsed regular monitoring programs shall include data management plans which have been developed in consultation or collaboration with the ICSU WDC Panel. These data management plans will provide details on which data, and in which formats, shall be submitted so that all data may be shared not only by the participants in any program but by all scientists.

- It is implicit in the agreements by adhering national bodies to ICSU that national participation in an ICSU-sponsored program includes the agreement to submit data according to these data management plans and the ICSU data exchange guides.

- The WDCs will operate on a long-term basis. If for any reason a WDC is closed, the data holdings shall be transferred to another appropriate WDC.

- The WDCs will accept data according to the data management plans of the respective ICSU scientific or monitoring program, store these data safely, and provide cost-effective access to the data by any user. WDCs may also seek and collect related data, in order to enhance the utility of the data holdings. The WDCs may, with advice from ICSU scientific bodies, prepare higher-order data products, such as indices of activity, collated data sets, or condensed data sets.

- WDCs will prepare and publish catalogues of data holdings.

- Data will be provided to any scientists on an exchange basis or, at most, at a cost not to exceed cost of copying.

- WDCs will make arrangements to accept any scientist as a visitor to work on site with data holdings held under WDC auspices.

For comprehensible reasons there were, originally (1957) two WDC groups, one in the USA (WDC-A) and one in the USSR (WDC-B), very soon complemented by a number of specialized WDC-C in Europe, later with WDC-C2 in Japan and, more recently WDC-D in China (see the table).
One of the reasons (of course not the only one) of such duplications was to take an insurance against losses.

2. The Case of Earth Tides in the different WDC

A- Despite the responsibility of a WDC-A Solid Earth Geophysics at Boulder it appears that Earth Tide Data were never collected in this WDC. As a matter of fact ICET WDC-C never received any data from the USA through this channel.

B- The WDC-B Solid Earth Geophysics at Moscow collected few Earth Tide data during IGY and transmitted them to ICET WDC-C until 1960 but this exchange was stopped soon and it is not known if such data collected from stations in the former USSR are stored presently in this WDC-B.

C2- Apparently there is no WDC in Japan collecting Earth Tide Data.
Few Data from Japan were received by ICET WDC-C directly from individual scientists.

D- We do not know if the WDC-D Geophysics at Beijing is collecting Earth Tide Data. At the exception of the measurements performed in China with the instruments of the Royal Observatory of Belgium and despite many requests, ICET WDC-C has received only few data from the Chinese stations.

C1-ICET-

It was recommended by the Permanent Commission of Earth Tides (International Association of Geodesy) to store all recorded data at the International Centre for Earth Tides in Brussels which is recognized and acts as WDC/C.
Up to now this has been accomplished to a large extent in several steps. Initially (but for a very short time) in the form of manually typed tables, then very soon on punched cards and magnetic tapes.
All the data stored at ICET have now been transferred on diskettes and we are now in the procedure to store them on optical disks.
To day the ICET Data Bank contains results from 355 tidal gravity stations but not all stations provided their initial hourly readings. The conservation of the data in the ICET World Data Centre C has the following advantages:

1) protection of the data against loss or damage. It has been our experience that when, for some reason, a scientist leaves his Institution, geophysical data upon which he worked may be difficult to retrieve and even, sometimes, are simply lost. In several cases indeed, ICET has already provided duplicates of data to Institutions which originally acquired them;

2) automatic and safe introduction of the submitted data into the ICET Data Bank.
The objectives of the Data Bank are summarized in section 5. Of course if, for some reason, protection is requested to avoid that some data should be made available to anybody this will be avoided by an appropriate key;

3) Institutions providing tidal gravity data to the ICET Data Bank have access, free of charge, to all data included in the Data Bank (at the exception of course of those with requested restricted access).
Having received new recommendations at the IUGG/IAG General Assembly in Vienna (august 1991) and also from the Walferdange brain-trust meeting organized in may 1992, I have urged all colleagues to transmit as soon as possible available tidal gravity data to ICET in the usual format and on diskettes (Section 6).
In particular, considering that they have already been exploited, those data which have been used and analyzed in published papers should be sent to ICET without delay.

3. The Storage of Earth Tide Data by ICET WDC-C

With few exceptions the measurements made by the different European groups working in the field have been sent to this Data Center and are presently stored on diskettes.
This concerns not only the measurements in Europe but also in other continents when made by European teams (Trans World Tidal Gravity Profiles for example).
It is to be pointed out that we are not the only ones to be faced with the problem of reading old magnetic tapes which contain the oldest measurements (period 1960-1970). In a WDC informal discussion meeting (october 1992) a need to build the tape drives needed to read old tapes in obsolete formats was mentioned.
We also wait until several colleagues will send us their data as promised.
It is planned to make a copy on CD-ROM as soon as the situation will be clarified.
The list of existing data (to our knowledge) is given in the "Directory of Gravimeters in use for Earth Tide measurements" reproduced hereafter.
In this Directory 903 series of tidal gravity data have been indexed. From this total only 525 could be collected and stored on diskettes at WDC/C-ICET, covering 3.055.469 hourly readings.
A similar Directory will be prepared later for tilt and strain measurements.

Considering the recommendation of the ICSU-WDC Panel:

> *"WDCs may also seek and collect related data, in order to enhance the utility of the data holdings"*.

we have introduced in the Data Bank not only the usual coordinates (latitude, longitude, height, continent) of the measuring site but also:

the distance to the nearest oceanic tidal area
the gravity value
the Bouguer anomaly
the Heat Flow density and Heat Flow province
the Crustal thickness
the Lithosphere thickness

information about volcanic areas

when available.

4. Data Rescue

We know that probably the original digitized data of more than 10 (perhaps 20) stations are lost. It may be that the analog registrations still exist and could be measured again.
In few cases, when the digitized data had been sent to ICET WDC-C this Centre was able to make a new copy for the concerned Institutions.
Earth Tides is not the only field where data have been lost, despite the existence of the WDC System.
Reasons for losses are multiple: normal moves in the scientific staffs of Institutions, incorrect or unconvertible storage system, closing of a department and even policial measures prohibiting the exchanges are only few examples we know due to diverse kinds of incidents as related in several letters received by ICET since december 1992:

- ... In view of structural changes in our laboratory we do not now possess, ala, the greater part of our gravity earth tide records of previous years.

- ... Unfortunately, I could not find oldest records, because persons engaged in this observational work are died ...

- ... The computing Centre which we used to exploit does not exist any more and all my data, kept on magnetic tapes, disappeared.

- ... Please give some time to read our tapes ...
  ... I have nobody to do the work right now.

- ... digitalized of (XXX) I loosed shortly after I analyzed it. The analog curves I have of course.

- ... if you can find the original hourly readings (they have gone lost here).

- ... I have been trying to that the original, jump-edited and calibrated -as-was data out of the ice of a backup copy at our data centre. But since the (admittedly special) storage technique that I applied back then is no longer supported on their new disks, I could not get the data back. Regrettably, the only contribution I can make is another entry in your black-book of ceased-to-be data.

At ICET also there is one very old tape that we have not yet been able to read!

Some people simply have refused to deliver their data to the WDC arguing that they keep them for their own researches at least during some time. But after 10 or even 20 years such data were never received. However it is to be pointed out that in such cases the WDC pledges one's faith not to use the data for its own purposes or to deliver them to anybody without explicit authorization.

5. Objectives of a Data Bank.

- gathering, storage, archiving and protection against loss
- compilation, accumulation, classification (geography)
- homogeneization, standardization, validation (format, orthography, notations)
- quality estimation and rejection criteria
- condensation
- detection of errors or inconsistencies
- retrieval (easy access)
- identification of gaps
- histograms, regressions and correlations
- perception of patterns (shape, visualization)
- trends and arrays
- testing theories
- interpretation
- prediction
- diffusion and dissemination

6. Format.

All tidal and related meteorological or hydrological data should be sampled at hourly intervals.
For an easy access to them it is strongly recommended to adopt a record format as close as possible to the so called International Format in which twelve hourly values are stored on each record:

Col 1	tidal components: --- 0 = V, 1 = NS, 2 = EW, 3 = wells, 4 = strain, 5 = tilt at 45° azimuth meteorological data: --- 6 = temperature, 7 = pressure
Col 2 - 4	instrument number
Col 5 - 8	station number

Col 9 - 13 integer part of julian date - minus 2400000

Col 14 - 15 year

Col 16 - 17 month

Col 18 - 19 day

Col 20 time of first hourly value 0 = 00h, 2 = 12h

The twelve hourly values may be given in any format.
It is suggested to use integer numbers with five positions (col 21-25 first value, ... col 76-80: twelfth value).
Interruption will be indicated by a record 9999 in col 1-4.

7. Directory of Gravity Meters in use for Earth Tide Measurements.

During numerous verifications made at ICET, it was realized that a "Directory of the Gravity Meters in use for Earth Tide Measurements" was needed to help to discover anomalies or contradictions in the instrumental calibrations, as well as systematic discrepancies between instruments engaged in campaigns of measurements at many different sites. The most recent version of this Directory is published hereafter in three parts:

Part I — Listing on file according to the Instruments Numbers
which allows to see where and when each instrument has been used to measure gravity tides and to follows its "history".

Part II — Listing on file according to the Stations Numbers
which allows to compare the results obtained with different instruments at one same station or in some geographical area with the aim of amplitude and phase calibration errors detection.

Part III — Listing of the owner Institutes of the Different Instruments
it is evidently hoped that each involved Institution will react by providing to ICET additional (or better) informations about the performances of its instruments.

As said before these listings cover not only the 525 tidal gravity series (3.055.469 hourly readings) which have been received at ICET from many stations (marked with *) but also other series reported in publications but not made available at ICET.
It is hoped very much that, at the receipt of this Directory, the concerned Institutes will realize how important it is for the future to have a copy of their data preserved in the ICET Data Bank.

8. Conclusion

Considering the errors made in the past, I can only urge all those who want to protect their own data against future loss to deliver them to the WDC-C with specification "communication free" (as I hope) or "classified until .... 1999" (or any other date).

WDC-A	Glaciology	Boulder CO	U.S.A.
WDC-A	Marine Geology & Geophysics	Boulder CO	U.S.A.
WDC-A	Meteorology	Asheville NC	U.S.A.
WDC-A	Oceanography	Washington D.C.	U.S.A.
WDC-A	Rockets & Satellites	Greenbelt MD	U.S.A.
WDC-A	Rotation of the Earth	Washington D.C.	U.S.A.
WDC-A	Seismology	Golden/Denver CO	U.S.A.
WDC-A	Solar-Terrestrial Physics	Boulder CO	U.S.A.
WDC-A	Solid Earth Geophysics	Boulder CO	U.S.A.
WDC-B1	Hydrometeorology	Obninsk	U.S.S.R.
WDC-B2	Solar-Terrestrial Physics	Moscow	U.S.S.R.
WDC-B2	Solid Earth Geophysics	Moscow	U.S.S.R.
WDC-B	Marine Geology & Geophysics	Gelendzhik	U.S.S.R.
WDC-C	Earth Tides	Brussels	Belgium
WDC-C1	Geomagnetism	Copenhagen	Denmark
WDC-C1	Geomagnetism	Edinburgh	United Kingdom
WDC-C	Glaciology	Cambridge	United Kingdom
WDC-C	Recent Crustal Motions	Prague	Czechoslovakia
WDC-C	Soil Geography & Classification	Wegeningen	Netherlands
WDC-C	Solar Activity	Meudon	France
WDC-C1	Solar-Terrestrial Physics	Chilton	United Kingdom
WDC-C	Sunspot Index	Brussels	Belgium
WDC-C2	Airglow	Tokyo	Japan
WDC-C2	Aurora	Tokyo	Japan
WDC-C2	Cosmic Rays	Toyokawa	Japan
WDC-C2	Geomagnetism	Kyoto	Japan
WDC-C2	Ionosphere	Tokyo	Japan
WDC-C2	Nuclear Radiation	Tokyo	Japan
WDC-C2	Solar Radio Emissions	Nobeyama	Japan
WDC-C2	Solar-Terrestrial Activity	Sagamihara	Japan
WDC-D	Geology	Beijing	China
WDC-D	Geophysics	Beijing	China
WDC-D	Glaciology & Geocryology	Lanzhou	China
WDC-D	Meteorology	Beijing	China
WDC-D	Oceanography	Tianjin	China
WDC-D	Renewable Resources & Environment	Beijing	China
WDC-D	Seismology	Beijing	China
WDC-D	Space Sciences	Beijing	China
WDC-D	Solar Astronomy	Beijing	China

DIRECTORY OF GRAVITY METERS IN USE FOR EARTH TIDE MEASUREMENTS

8 february 1994

PART I: On File according to the Instruments Numbers

	INSTRUMENTS	Number of records	
A	- ASKANIA GS 11, GS 12	113	
A*	- ASKANIA GS 15	94	
A#	- ASKANIA GS 25	2	
AB	- ASKANIA modified by M. Bonatz	48	
AD	- ASKANIA modified by Dittfeld and Neumeyer	5	
AR	- ASKANIA modified by I. Rogatnev	1	
			= 263
G	- GEODYNAMICS	210	
			= 210
L	- LACOSTE ROMBERG model G	173	
LD	- LACOSTE ROMBERG model D	31	
LZ	- LACOSTE ROMBERG with zero method	112	
			= 316
ET	- LACOSTE ROMBERG Earth Tide/mechanical feedback	55	
ET*	- LACOSTE ROMBERG Earth Tide/electronic feedback	19	
			= 74
GWR	- SUPERCONDUCTING gravimeter	20	
UCSD-	SGA/B SUPERCONDUCTING gravimeter	5	
UCSD		3	
			= 28
	Others	2	
	NA	4	
	NAB	4	
	LCR D/G	2	
			= 12
		Total	903

g number of gaps
d number of days of installation
r number of hourly readings
e efficiency R/24D

H Data of historical interest only
D Data to be discarded for technical reasons
X Data replaced by more recent and more precise data

* preceding the station's name indicates that the data are on diskette in ICET library

number of * series = 525
total number of * hourly readings = 3.055.469

Directory of Gravimeters in use for Earth Tide Measurements

Instr.				Station	Epoch	g	d	r	e
?	23	3401	H	BAMAKO	65 01 00 - 65 04 00			2160	
A	25	2201		TEHERAN	81 02 19 - 81 11 15	27	271	3120	0.48
A	79	0711	D	BERCHTESGADEN	83 07 21 - 84 05 19	1	305	5136	0.70
AB	79/3	0711	*	BERCHTESGADEN	77 08 23 - 83 06 07	64	2116	25680	0.51
A	85	0701		BONN	65 01 14 - 69 03 19				
A	85	0004	*	LONGYEARBYEN	69 09 03 - 70 06 06	3	278	6336	0.95
AB	85/2	0701		BONN	72 12 02 - 73 03 11		101		
AB	85/2	0701		BONN	73 09 05 - 73 11 15	2	62	1476	0.99
AB	85/2	0842	*	OSLO	74 02 20 - 74 04 07	0	48	1152	1.00
AB	85/2	0843	*	BERGEN	74 05 28 - 74 08 15	4	81	1776	0.91
AB	85/2	0844		TRONDHEIM	74 09 09 - 75 04 07	-	159	-	-
AB	85/2	0846	*	BODOE	75 04 14 - 75 10 03	6	175	2880	0.69
AB	85/2	0847	*	TROMSOE	75 10 14 - 76 01 16	6	96	1968	0.85
AB	85/2	7305	*	CURITIBA	83 04 16 - 85 04 28	26	746	15456	0.86
A	97	0505		GENOVA	60 10 16 - 62 12 30	2	806	15336	0.79
A	99	7201	H	CARACAS	59 10 31 - 63 07 18	2	1356	32544	
A	105	2847	H	MIZUSAWA	68 09 02 - 68 11 15	0	76		
A	108	0509		TRIESTE	59 07 02 - 60 07 09	1	374	8160	0.91
A	108	0507		COSTOZZA	62 09 07 - 62 12 08	1	92	1440	0.65
AB	108/10	0701		BONN	75 01 11 - 75 07 06	0	177	4246	
A	110	0905	*	VARSOVIE	71 06 16 - 72 02 23	11	254	5184	0.85
AB	110/17	0905	*	VARSOVIE	80 01 15 - 82 04 18	22	826	18144	0.92
A	111	2823	H	KYOTO	59 08 01 - 60 08 17	0	383	9192	1.00
A	111	2847	H	MIZUSAWA	68				
AD	112	0905	*	VARSOVIE	80 01 08 - 83 05 10	29	1221	26064	0.89
A	116	0701		BONN	65 09 20 - 66 06 12				
A	116	0701		BONN	66 07 14 - 69 04 13			994	
A	116	0004	*	LONGYEARBYEN	69 09 19 - 70 06 15	5	271	6240	0.96
A	119	2201		TEHERAN	64 08 30 - 70 11 12	17	2263	39600	0.73
A	119	2201		TEHERAN	74 07 03 - 76 09 22	57	811	8784	0.45
A	120	0550	H	PALERMO	63 06 29 - 63 09 25		90		
A	124	1142	H	KIEV	60 12 23 - 61 07		175	4200	
A	124	3401	H	BAMAKO	64 12 23 - 65 03 25			2256	
A	124	1117	H	OBNINSK	68 06 28 - 68 11 26		152		
A	124	1119		KR.PAKHRA	68 12 01 - 70 08		77	5000	
A	126	1270		TASHKENT	59 11 - 60 06		179	4296	
A	126	1142	H	KIEV	60 - 61				
A	126	1280	H	FRUNZE/BISHKEK	60 11 - 61 07		227	4680	
A	126	1293		TALGAR	61 11 11 - 67 06		1857	44520	
A	127	0765	H	POTSDAM	63 01 19 - 63 02 18	0	32		
A	127	0766	H	FREIBERG	63 03 10 - 63 07 31	1	62		
A	127	0763	H	BAD SALZUNGEN	63 08 09 - 63 09 28	0	52		
A	127	0761	H	KIESELBACH	63 10 16 - 63 11 23	0	40		
A	127	0769	H	BERGGIESHUEBEL	64 02 29 - 64 04 27	0	60		
A	130	0709	X *	HANNOVER	64 12 25 - 65 04 08				
A	130	0709	X *	HANNOVER	71 01 24 - 73 07 14	22	905	7152	0.33
A	130	0710	*	BAD GRUND	72 03 23 - 72 06 14	2	85	1536	0.76
AB	130/5	0701		BONN	74 06 16 - 74 09 09	6	45	1030	

Directory of Gravimeters in use for Earth Tide Measurements

Instr.					Station	Epoch	g	d	r	e
AB	130/5	0709	X	*	HANNOVER	74 09 22 - 76 08 11	8	691	6432	0.39
A	131	0928			CESKE BUDEJOVICE					
A	131	0930		*	PECNY	70 09 03 - 75 07 05	52	1768	16704	0.39
A	131	0928		*	CESKE BUDEJOVICE	72 03 11 - 73 03 05	25	361	6384	0.74
A	131	0930		*	PECNY	76 07 09 - 77 08 18	16	407	7200	0.74
A	131	0930		*	PECNY	77 12 07 - 80 07 05	62	943	9024	0.40
A	133	0923	H	*	PRIBRAM	68 09 02 - 68 12 05	0	96	2304	1.00
A	133	0928		*	CESKE BUDEJOVICE	72 07 23 - 73 09 16	21	422	6576	0.65
A	134	1270			TASHKENT	59 11 - 60 06		179	4296	
A	134	1142	H		KIEV	60 - 61				
A	134	1280	H		FRUNZE/BISHKEK	60 10 - 61 07		195	5448	
A	134	1293			TALGAR	61 11 11 - 71 08		1445	34680	
A	135	1142	H		KIEV	60 08 04 - 61 02		180	4320	
A	135	3401	H		BAMAKO	65 01 03 - 65 03 27	1	68	1632	
A	135	1117	H		OBNINSK	68 12 27 - 69 05 07		132		
A	135	1117	H		OBNINSK	70 05 16 - 72 01 04		303		
A	135	1117	H		OBNINSK	74 02 10 - 75 08 11		423		
A	137	9955			MOLODJOSHNAJA					
A	137	0765	H		POTSDAM	70 05 - 75		1298	1032	
A	138	0705	H		KARLSRUHE	62 - 65				
AB	138/6	0701			BONN	75 02 27 - 75 07 18	0	140	3382	
AB	138/6	0871	D		STORUMAN	83 04 03 - 83 08 29	9		1262	
AB	138/6	0827	D		ALBORG	84 08 29 - 85 01 27				
A	141	0511			RESINA	66 03 02 - 68 07 21	0	874	20976	1.00
AB	143/15	0202		*	DOURBES	85 11 22 - 89 04 18	32	1246	25392	0.85
AB	144	1190			TBILISSI/DUSHETI					
A	145	0201	X	*	BRUXELLES	58 07 02 - 64 05 09	10	1438		
A	145	0201	X	*	BRUXELLES	66 06 11 - 67 06 08	1	322	7704	0.99
AB	145/9	0701			BONN	74 07 15 - 74 11 03	6	90	2170	
AB	145/9	0257		*	WALFERDANGE	75 10 26 - 87 12 25	199	4445	75216	0.71
A	146	0713			HELGOLAND	63 08 04 - 65 09 08	5	230	5520	
A	147	1102	H		TALLINN	65 11 - 77 07 10	4	609	13536	
AR	147/2	1102			TALLINN	85 06 29 - 86 11 25	1	515	11520	
A	149	2607			WUHAN	72 01 08 -		174	4176	
A	150	2605			LANZHOU	??				
A	159	1152	H		POLTAVA	61 09 06 - 64 01 30	6	876	17136	0.82
A	159	1150			SIMFEROPOL	65 01 17 - 66 05 22	15	491	11088	0.94
A	159	1151			YALTA	66 06 29 - 68 06 16	12	781	15504	0.90
A	159	1289			NOVOSIBIRSK	66 12 - 70 12				
A	159	1165			BAKHTCHISSARAI 1	68 08 02 - 68 11 23		114	1848	0.68
A	159	1165			BAKHTCHISSARAI 2	70 02 07 - 71 01 26		543	8808	0.68
A	159	1152	H		POLTAVA	73 11 27 - 75 09 29		640	15360	0.97
A	159	1152	H		POLTAVA	75 11 16 - 76 12 26		407	9768	0.98
A	159	1152			POLTAVA	87 11 28 - 91 11 30		1799	43176	0.98
A	160	0201	X	*	BRUXELLES	60 04 03 - 63 03 08	3	876		
A	160	0251		*	LUXEMBOURG	63 04 15 - 70 09 30	51	2086	50064	
AB	160/3	0701			BONN	74 01 26 - 74 04 30	2	80	1924	
AB	160/3	0201	X	*	BRUXELLES	74 05 14 - 74 10 17	12	158	4608	0.61
AB	160/3	0257	X	*	WALFERDANGE	76 08 16 - 78 04 05	39	599	9312	0.65

Directory of Gravimeters in use for Earth Tide Measurements

Instr.					Station	Epoch	g	d	r	e
A	162	0765	H		POTSDAM	63 01 19 - 63 02 18	0	32		
AD	162	0765			POTSDAM	84 01 - 84 12				
AD	162	0762			TIEFENORT	85 - 91 01 01				
A	166	1190			TBILISSI/DUSHETI	60 00 -				
A	167	1293			TALGAR	67 08 07 - 77 07		3015	70896	
A	167	1293			TALGAR	72 12 27 - 78 09 03				
A	167	1293			TALGAR	78 09 28 - 79 09 18				
A	167	1293			TALGAR	81 04 01 - 81 03 30				
A	168	0861	H		STOCKHOLM	63 04 10 - 67 01 13	34	1154		
A	168	0861	H		STOCKHOLM	67 12 22 - 68 04 24	6	192		
A	168	0861		*	STOCKHOLM	74 05 10 - 74 07 03	1	57	1248	0.92
AB	171/4	1001			CALDARUSANI	75 02 10 - 75 06 29	1	127	3284	
A	175	0213	H		BATTICE	63 04 13 - 63 10 02	0	174		
A	175	0213	H		BATTICE	64 02 15 - 64 09 25	1	224		
A	175	0217	H		DINANT	68 05 03 - 70 01 30	15	590		
A	175	0212	D	*	COINTE	71 02 10 - 72 03 04	11	390	8208	0.88
AB	175/13	0257	X	*	WALFERDANGE	79 03 16 - 81 05 04	59	782	9120	0.49
A	180	1289			NOVOSIBIRSK	66 12 - 70 12			17304	
A	180	1119			KR.PAKHRA	67 10 -		862	2520	
A	180	1119			KR.PAKHRA	70 05 - 72 05			17592	
A	180	1300			IRKUTSK	79 09 - 88 02				
A	185	1165			BAKHTCHISSARAI 1	68 07 26 - 69 02 14		202	2904	0.60
A	185	1165			BAKHTCHISSARAI 2	70 05 20 - 71 09 07		566	8592	0.63
A	185	1152	H		POLTAVA	73 11 25 - 74 04 13	0	138	3312	1.00
A	185	1152	H		POLTAVA	76 01 08 - 76 11 26		324	7776	0.99
A	185	1152			POLTAVA	80 04 21 - 81 09 30	0	528	12672	1.00
A	185	1159	D		SIMEIZ	81 10 20 - 84 12 25		1162	20160	0.72
A	185	1152			POLTAVA	87 11 28 - 89 04 26		516	12384	0.99
A	186	1289			NOVOSIBIRSK	66 12 - 70 12		989		
A	186	1293			TALGAR	74 01 - 74 12		356	8544	
A	186	1300			IRKUTSK	79 09 - 88 02			22372	
A	186	1289		*	NOVOSIBIRSK	85 05 18 - 90 08 18	60	1920	30816	0.67
A	187	0882	D		HELSINKI 1	64 09 26 - 66 05 21	20	356		
A	187	0882		*	HELSINKI 1	66 05 28 - 67 05 21	2	354		
A	187	0883			HELSINKI 2	67 06 10 - 73 04 03		596		
AB	187/20	0891		*	VIROJOKI	83 02 24 - 83 04 29	3	66	672	0.42
AB	187/20	0882		*	HELSINKI 1	84 01 29 - 84 06 07	2	131	2880	0.92
A	188	0765	H		POTSDAM	73 07 07 - 78 06 04			1264	
AD	188	0765			POTSDAM	86 03 26 - 86 07 03	0	99		
AD	188	0905		*	VARSOVIE	86 08 02 - 89 04 60	28	1004	22416	0.93
A	190	0952	H		TIHANY	62 - 66				
A	190	0952	H		TIHANY	66 06 06 - 72 10 07	32	1437		
A	190	1117	H		OBNINSK	73 01 22 - 73 12 20		333	7992	1.00
A	190	0955		*	PECS	78 02 16 - 78 06 04	7	110	1344	0.51
AB	190/7	0956			PENC	-			1920	
AB	190/7	0701			BONN	74 08 15 - 74 10 30	7	80	1916	
AB	190/7	0952			TIHANY	74 12 11 - 75 01 19	0	40		
AB	190/7	0930		*	PECNY	75 02 16 - 75 05 25	2	99	2064	0.87
AB	190/7	1117	H	*	OBNINSK	75 08 22 - 76 06 13	5	235	5424	0.97

Directory of Gravimeters in use for Earth Tide Measurements

Instr.					Station	Epoch	g	d	r	e
AB	190/7	1105		*	POULKOVO	76 05 13 - 76 10 20	0	158	3792	1.00
AB	190/7	0952		*	TIHANY	77 06 18 - 78 01 22	2	220	4848	0.92
AB	190/7	0765	X	*	POTSDAM	79 01 13 - 79 12 09	0	332	7968	1.00
AB	190/7	0695		*	GRAZ	80 07 16 - 81 05 18	7	309	7152	0.97
AB	190/7	0950		*	BUDAPEST	82 03 11 - 83 12 29	30	660	13776	0.87
AB	190/7	0950			BUDAPEST	84 11 02 - 86 01 01				
AB	190/7	0701			BONN	86 11 21 - 87 06 30	3	222	624	
AB	190/7	0950			BUDAPEST	88 04 05 - 88 09 05				
A	191	0201	X	*	BRUXELLES	65 06 04 - 67 12 02	18	518		
AB	191/1	0701			BONN	73 07 30 - 73 10 24	1	81	1926	
AB	191/1	0201	X	*	BRUXELLES	74 01 17 - 74 08 21	7	219	9504	0.91
AB	191/1	0257		*	WALFERDANGE	74 12 25 - 92 11 18	230	6556	121344	0.77
A	193	2847	H		MIZUSAWA	68 09 01 - 68 11 16	0	78		
A	197	2847	H		MIZUSAWA	67 11 02 - 68 11 15	1	198		
A	197	2848			AKAGANE	69 09 09 - 69 10 11	0	34	816	1.00
A	197	2847			MIZUSAWA	72 01 02 - 72 12 30	11	365	5712	0.65
A	201	1105			POULKOVO	76 05 13 - 76 10 06		128	3204	1.00
AB	201/26	0930			PECNY	83 04 10 - 86 01 06	54	1004	18384	0.76
AB	201/26	1280		*	FRUNZE/BISHKEK	89 01 02 - 90 04 21	16	477	10320	0.90
AB	202/11	0701			BONN	75 02 08 - 75 04 27	0	79	1894	
AB	202/11	0862	X		DANNEMORA	75 08 13 - 75 10 11	0	60	1438	-
AB	202/11	0862		*	DANNEMORA	76 01 23 - 82 11 29	34	2505	37968	0.63
A*	204	0715		*	KIEL	70 01 20 - 70 04 14	0	86	2064	1.00
A*	204	0715			KIEL	72 02 18 - 72 07 09		142		
A*	204	0714			BUESUM	72 07 11 - 73 07 10		364		
A*	204	0823			BORNHOLM	73 07 26 - 73 09 02		38		
A*	204	0715			KIEL	73 10 08 -				
A*	205	2636			ZHENZHOU	81 04 02 - 92 12 31				
A*	206	0004		*	LONGYEARBYEN	70 05 05 - 70 06 14	2	42	792	0.78
A*	206	0701			BONN	70 11 27 - 71 03 12	0	108	2592	1.00
A*	206	0201	X	*	BRUXELLES	71 03 20 - 71 06 22	1	96	2256	0.98
A*	206	0256	X	*	WALFERDANGE	71 07 02 - 71 11 11	7	134	2640	0.82
A*	206	0300		*	STRASBOURG 1	71 12 21 - 72 03 04	0	76	1824	1.00
A*	206	0701			BONN	72 03 09 - 72 10 20		223		
A*	206	9904			KERGUELEN	73 01 05 - 74 01 28	9	391	8928	0.95
A*	206	3620			REUNION	74 05 27 - 75 10 18	19	511	11136	0.91
A*	206	3901			WINDHOEK	76 04			2652	
A*	206	0750			BERLIN	79 01 02 - 79 04 11				
A*	206	0848		*	NESNA	80 04 15 - 80 12 13	11	244	5232	0.89
A*	206	0845			HEMNESBERGET	83 03 25 - 83 10 15	0	204	4896	1.00
A*	206	0825			VARDE	85 05 02 - 85 05 11				
A*	206	0828			ROLFSTED	86 04 04 - 86 07 02				
A*	206	0830			MOGELTONDER	87 05 10 - 87 09 12				
A*	206	0829			KOBENHAVN	88 05 03 - 88 08 20		58		
A*	207	2633			QUANZHOU	82 04 15 - 82 07 27	6	104	2256	0.90
A*	210	0715		*	KIEL	70 02 09 - 70 04 14	0	66	1584	1.00
A*	210	0201	X	*	BRUXELLES	71 08 13 - 71 12 05	3	114	3360	0.60
A*	210	0701			BONN	71 12 10 - 72 01 19	0	42	1008	1.00
A*	210	0715			KIEL	72 02 18 - 72 09 25		142		

Directory of Gravimeters in use for Earth Tide Measurements

Instr.				Station	Epoch	g	d	r	e
A*	210	0713		HELGOLAND	72 07 17 - 73 10 24		100		
A*	210	0890	*	VAAJAKOSKI	82 02 08 - 82 07 23	7	168	3504	0.87
A*	210	0750		BERLIN	84 01 16 - 84 05 03				
A*	210	0826		MONSTED	84 05 31 - 84 11 19				
A*	210	0827		ALBORG	85 02 23 - 86 06 14		381		
A*	210	0824		SOEGARD	86 05 05 - 86 07 07				
A*	210	0829		KOBENHAVN	87 08 05 - 87 11 26				
A*	211	2604		KUNMING	75 04 12 - 79 02 28				
A*	211	2604		KUNMING	78 11 25 - 81 01 01		606		
A*	211	2604		KUNMING	81 01 01 - 92 12 31				
A*	212	0402	*	MADRID	73 12 12 - 76 03 27	22	838	4272	0.21
A*	212	0201	X *	BRUXELLES	74 07 08 - 74 12 19	10	166	7104	0.89
A*	212	3210	*	BU CRAA	75 03 24 - 75 10 10	19	202	3024	0.62
A*	212	0403	D *	GRANADA	76 04 03 - 76 06 20	7	81	1296	0.67
A*	212	0401	*	VALLE D.L.CAIDOS	76 08 08 - 79 05 21	24	1019	5904	0.24
A*	212	0405	*	BURGOS	76 12 15 - 77 05 28	7	166	3648	0.92
A*	212	0407	D *	SEPULVEDA	77 07 03 - 77 12 06	11	158	2736	0.72
A*	212	0201	X *	BRUXELLES	78 03 18 - 78 09 26	6	194	4320	0.93
A*	212	0401	*	VALLE D.L.CAIDOS	80 05 01 - 82 10 19	24	903	14784	0.68
A*	213	2643		PIXIAN	81 01 01 - 92 12 31				
A*	215	2642		YINCHAN	82 03 22 - 92 12 31				
A*	215	2626	*	YINCHUAN	93 01 04 - 93 06 12	2	161	3744	0.97
A*	216	2606	*	URUMQI	80 03 28 - 80 09 26	4	184	4224	0.96
A*	216	2606		URUMQI	81 01 01 - 92 12 31				
A*	217	2823	H	KYOTO	72 06 - 75 05		1095	7520	0.67
A*	217	2823	*	KYOTO	82 11 02 - 83 05 29	3	210	4752	0.94
A*	218	2605	*	LANZHOU	80 03 30 - 80 09 28	5	184	4176	0.95
A*	218	2606		URUMQI	82 09 02 - 92 12 31				
A*	219	0715		KIEL	72 02 18 - 72 09 25		220		
A*	220	1117		OBNINSK	73 04 27 - 73 12 25		121		
A*	220	0952	*	TIHANY	73 09 26 - 74 06 23	3	272	6144	0.94
A*	220	1117	D	OBNINSK	74 08 28 - 76 04 19		202		
A*	220	0930		PECNY	75 01 31 - 75 05 29	2	118	2772	-
A*	220	1117	*	OBNINSK	75 11 30 - 76 04 17	1	142	3360	0.99
A*	220	1105	*	POULKOVO	76 05 25 - 77 01 15	1	238	5664	0.99
A*	220	1117	*	OBNINSK	77 02 12 - 77 11 29	12	289	6384	0.92
A*	220	1010	*	SOFIA	78 01 22 - 79 02 11	16	385	7728	0.84
A*	220	1117		OBNINSK	79 05 11 - 81 01 19		620		
A*	221	1117	D *	OBNINSK	75 08 30 - 76 04 18	3	232	5280	0.95
A*	221	1117	*	OBNINSK	77 05 19 - 78 01 30	12	258	5616	0.91
A*	221	1010	*	SOFIA	78 02 19 - 79 02 10	14	358	7440	0.87
A*	222	0765	*	POTSDAM	74 03 22 - 90 06 06	15	5922	129738	0.91
A*	222	0930		PECNY	75 02 04 - 75 05 16	5	103	1728	-
A*	222	0765	*	POTSDAM	82 02 26 - 93 03 30	2	4052	93360	0.96
A*	224	0952		TIHANY	74 02 04 - 74 06 23		140		
A*	224	1117	D	OBNINSK	76 12 15 - 78 12 05		690	5436	
A*	224	0864	*	UPPSALA	81 04 03 - 82 09 13	12	530	10944	0.86
A*	224	0860		GÖTEBORG	84 06 20 - 85 03 04	4	257	5617	0.91
A*	226	0201	X *	BRUXELLES	74 01 09 - 74 03 08	5	60	2304	0.80

Directory of Gravimeters in use for Earth Tide Measurements

Instr.			Station	Epoch	g	d	r	e
A*	226	2502	* CHIANG MAI	74 04 12 - 74 09 01	16	144	1920	0.56
A*	227	2613	SHANGHAI TUNEL	78 04 - 78 08		142		
A*	227	2613	SHANGHAI	81 01 03 - 83 08 30				
A*	227	2607	WUHAN	85 06 01 - 86 06 30				
A*	227	2644	XIAGUAN	86 10 01 - 92 12 31				
A*	227	2641	* DALI	93 01 02 - 93 06 29	7	180	3696	0.86
A*	228	0930	* PECNY	76 04 23 - 92 01 01	240	5733	84912	0.62
A*	228	1010	* SOFIA	81 12 06 - 82 12 05	6	366	8208	0.94
A*	228	0950	* BUDAPEST	84 11 02 - 85 12 04	12	399	8160	0.85
A*	229	2645	DUKOU	81 01 01 - 92 12 31				
A*	230	2646	MIDU	84 01 01 - 92 12 31				
A*	231	2637	PI COUNTRY/SICHUAN			94		
A*	231	2603	BEIJING			378		
A*	231	2650	LHASA			134		
A*	231	2604	KUNMING	80 02 03 - 80 08 16		196		
A*	231	2612	SHANGHAI	80 09 21 - 81 04 16		180		
A*	232	2618	BAODI	83 01 01 - 92 12 31				
A*	232	2618	* BAODI	93 01 02 - 93 06 28	1	179	4224	0.98
A#	233	0702	* EFFELSBERG	77 10 28 - 80 01 11	32	807	15552	0.80
A#	233	0257	* WALFERDANGE	80 12 24 - 93 01 08	107	4401	86784	0.82
ET	4	9998	* SOUTH POLE	74 01 02 - 74 03 31	0	90	2160	1.00
ET	5	0306	STRASBOURG 2	73 08 06 - 79 05 03	53	2098	35184	0.70
ET	5	0306	STRASBOURG 2	82 06 02 - 85 06 24	16	1121	24000	0.89
ET	6	9998	SOUTH POLE	74 01 - 74 03			2160	
ET	10	0150	* EDINBURGH	86 03 01 - 86 07 08	1	131	2208	0.70
ET*	10	0101	* BIDSTON	84 05 26 - 84 11 24	0	184	4416	1.00
ET*	10	7305	* CURITIBA	87 12 05 - 88 06 04	0	194	4656	1.00
ET	12	6803	* OTTAWA	67 03 23 - 74 12 30	53	2841	24048	0.87
ET	12	6804	* HOLLAND MILLS	70 04 30 - 70 06 13	1	46	816	0.74
ET	12	6811	* ALERT	71 05 11 - 71 08 21	0	104	2496	1.00
ET*	13	0101	BIDSTON		0	183		
ET*	13	0201	* BRUXELLES	84 10 11 - 85 02 14	0	128	3072	1.00
ET*	13	0615	* ZUERICH	85 11 21 - 86 06 21	0	214	5136	1.00
ET*	13	0610	* CHUR	87 07 03 - 87 10 13	0	105	2520	1.00
ET	15	0101	BIDSTON		0	183		
ET	15	0111	* LONDON	72 04 30 - 72 07 01	0	64	1536	1.00
ET	15	0112	* TAUNTON	72 08 08 - 72 09 29	0	54	1296	1.00
ET	15	0114	* REDRUTH	73 03 10 - 73 07 22	3	136	2208	0.68
ET	15	0116	* NEWTOWN	75 01 13 - 75 04 02	1	81	1344	0.69
ET	15	0401	* VALLE D.L.CAIDOS	79 02 14 - 79 11 09	11	270	5184	0.80
ET	15	2607	* WUHAN	87 05 05 - 88 04 06	0	314	7536	1.00
ET*	15	0734	* BAD HOMBURG	84 01 05 - 84 07 07	0	186	4460	1.00
ET	16	0733	DARMSTADT	72 12 06 - 73 06 12	0	188	4510	
ET	16	0733	DARMSTADT	73 07 11 - 73 12 09	0	151	3630	
ET	16	0707	HEIDELBERG	73 12 19 - 74 03 01				
ET	16	0718	OBRIGHEIM	73 12 20 - 74 02 28	1	70	1272	
ET	16	0615	ZUERICH	74 03 07 - 74 04 16	0	40	968	
ET	16	0719	STUTTGART	74 04 20 - 74 05 20	2	30	538	
ET	16	0737	MUENCHEN	74 05 24 - 74 06 24	1	31	668	

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Instr.				Station	Epoch	g	d	r	e
ET	16	0711		BERCHTESGADEN	74 07 07 - 74 08 17	2	28	336	
ET	16	0750	D	BERLIN	74 08 22 - 74 10 06	3	33	790	0.72
ET	16	0732		BRAUNSCHWEIG	74 10 11 - 74 11 10	1	28	666	
ET	16	0715		KIEL	74 11 14 - 74 12 09		25		
ET	16	0735		MUNSTER	74 12 13 - 75 01 07	0	25	607	
ET	16	0739		WOLFSTEIN	75 01 18 - 75 03 31	1	73	1556	
ET	16	0315		SEVRES BIPM	75 04 10 - 75 05 29	1	49	1137	0.97
ET	16	0736		WUERZBURG	75 09 28 - 75 11 03	0		877	
ET	16	0706		FRANKFURT	75 12 18 - 76 02 08	0	52	1258	
ET	16	0615		ZUERICH	76 07 27 - 78 04 03			15019	
ET	16	0952		TIHANY	83 -				
ET*	16	2607		WUHAN	85 - 89 01				
ET*	16	2612		SHANGHAI ZO SE	89 01 - 89 12				
ET*	16	0765		POTSDAM	90 08 07 - 91 04 10	4	244		
ET*	16	2605	*	LANZHOU	92 08 28 - 93 10 03	16	403	8688	0.90
ET	17	2845		TSUKUBA	81 04 17 - 81 12 16	11	254	4683	0.80
ET	17	2845		TSUKUBA	82 06 15 - 85 09 09	93	1183	23845	0.84
ET	17	2827		IZU-OSHIMA	85 09 20 - 89 03 20	231	1278	22320	0.73
ET	17	2845		TSUKUBA	89 05 19 - 89 08 26	3	100	2365	0.99
ET	17	2845		TSUKUBA	90 02 15 - 90 07 02	6	138	2545	0.77
ET	18	0712	*	CLAUSTHAL	76 02 10 - 76 06 19	0	132	3168	1.00
ET	18	0709	X *	HANNOVER	76 06 24 - 78 01 10	4	567	11376	0.84
ET	18	0750		BERLIN	78 09 07 - 80 02 21	13	399	9579	
ET	18	0849	*	UMBUKTA	80 04 08 - 81 01 06	6	275	4896	0.74
ET	18	0870		TARNABY	82 02 20 - 82 06 02	0	120	2863	1.00
ET	18	0881	*	LOHJA	85 08 18 - 86 04 14	11	241	4752	0.82
ET*	18	0829		KOBENHAVN	86 11 09 - 87 02 26		110		
ET*	18	0892	*	METSÄHOVI	87 05 24 - 91 10 25	27	1617	30672	0.79
ET*	19	0716		SCHILTACH	80 09 26 - 82 08 15		689		
ET*	19	0716	*	SCHILTACH	88 12 08 - 89 04 10	1	125	2880	0.96
ET*	19	0716		SCHILTACH	90 07 07 - 90 10 29		114		
ET*	19	0716	*	SCHILTACH	91 02 15 - 91 11 27	0	286	6864	1.00
ET	20	2640		HINADO	83 01 09 - 83 03 22	6	73	1344	0.77
ET	20	2650		LHASA	83 05 17 - 83 10 01	4	142	2928	0.86
ET	20	2638		HEIFEI	84 02 17 - 84 05 14	3	87	1324	0.87
ET	20	2621		CHENGDE	84 12 07 - 85 08 02	4	239	5424	0.94
ET	20	2607		WUHAN	86 12 22 - 87 08 29	0	190	4560	1.00
ET	21	2650		LHASA	83 05 17 - 83 10 01	6	142	2832	0.83
ET	21	2636		ZHENZHOU	84 01 18 - 84 07 21	3	185	4224	0.95
ET	21	2619		WAN XIAN	84 08 07 - 85 01 20	5	167	3792	0.95
ET	21	2607		WUHAN	85 05 30 - 88 04 05	19	1042	23616	0.94
ET*	21	2607		WUHAN	92 08 01 - 92 10 20				
ET*	21	2648		DUNHUANG	93 -				
ET	22	2607		WUHAN	86 09 11 - 87 06 30				
ET	22	2647		LIJIAN	90 08 01 - 92 07 30				
G	17	6337	*	MORGANTOWN	82 07 23 - 82 10 31	0	102	2448	1.00
G	17	6328	*	COLUMBIA	84 07 21 - 85 01 31	0	196	4704	1.00
G	17	6336	*	CHARLOTTESVILLE	85 07 14 - 86 01 15	1	187	3408	0.76
G	31	6004	*	UWEKAHUNA	78 01 29 - 78 12 17	10	324	6912	0.89

Directory of Gravimeters in use for Earth Tide Measurements

Instr.			Station			Epoch		g	d	r	e
G	74	0201	X	*	BRUXELLES	72 08 25	- 72 11 25	1	91	2088	0.96
G	74	0271		*	WITTEVEEN	72 12 01	- 73 03 31	3	123	2784	0.95
G	74	0709	X	*	HANNOVER	73 04 06	- 73 09 09	3	159	3600	0.95
G	74	0201	X	*	BRUXELLES	73 12 15	- 74 06 30	2	174	4176	
G	74	0216	D		KANNE	74 11 08	- 77 10 25	19	890	21360	?
G	74	0221		*	LOUVAIN LN	82 08 07	- 83 01 08	5	156	3264	0.87
G	74	0226		*	DAMME	83 02 09	- 83 09 05	16	210	2640	0.52
G	84	0201	X	*	BRUXELLES	71 07 09	- 73 11 08	35	855	16896	0.82
G	84	2501		*	BANGKOK	73 11 17	- 74 03 15	8	120	2208	0.77
G	84	2502		*	CHIANG MAI	74 04 09	- 74 09 08	14	154	2928	0.79
G	84	2450		*	KATHMANDU	74 09 30	- 75 03 13	15	165	1776	0.45
G	84	4206		*	CANBERRA	75 04 04	- 75 07 03	3	91	2064	0.95
G	84	4205		*	ARMIDALE	75 07 17	- 76 01 24	9	191	3840	0.84
G	84	4209		*	ALICE SPRINGS	76 02 11	- 79 01 04	25	1060	14736	0.58
G	84	0201	X	*	BRUXELLES	79 01 30	- 79 07 09	12	160	3216	0.84
G	84	2607		*	WUHAN	79 10 08	- 80 02 15	3	132	3024	0.95
G	84	2606		*	URUMQI	80 03 25	- 80 09 25	6	185	4128	0.93
G	84	2610		*	SHENYANG	80 10 14	- 81 11 19	11	403	5952	0.62
G	84	2614		*	TSING TAO	81 11 26	- 82 10 21	12	326	7008	0.90
G	84	2750		*	SEOUL	82 10 29	- 83 05 28	10	213	2544	0.50
G	84	0201	X	*	BRUXELLES	83 06 30	- 84 07 20	15	388	7152	0.77
G	84	7505		*	SANTA CRUZ 1	84 08 05	- 85 03 13	11	222	1920	0.36
G	84	7409		*	NANA	85 03 31	- 85 10 13	8	197	4176	0.88
G	84	7411		*	IQUITOS	85 10 24	- 86 04 24	2	184	4272	0.97
G	84	7412		*	NAZCA	86 05 05	- 86 10 22	6	172	3696	0.90
G	84	7451		*	GUAYAQUIL	86 11 18	- 87 04 20	7	154	2880	0.78
G	84	7251		*	CARTAGENA	87 05 01	- 87 09 27	7	150	3168	0.88
G	84	7252		*	IS.SAN ANDRES	87 11 27	- 88 05 19	3	176	4032	0.96
G	84	7253		*	CUCUTA	88 05 26	- 88 10 03	6	131	2880	0.92
G	84	7201		*	CARACAS	88 12 01	- 89 05 19	7	172	3840	0.93
G	84	0201	X	*	BRUXELLES	89 06 05	- 90 07 24	14	417	8688	0.87
G	84	0201	X	*	BRUXELLES	91 10 20	- 91 11 24	1	36	816	0.93
G	84	0201	X	*	BRUXELLES	93 09 15	- 94 01 11	7	120	2160	0.75
G	151	0201	X	*	BRUXELLES	75 09 17	- 76 02 18	12	156	5952	1.59
G	151	0695	D	*	GRAZ	80 07 16	- 81 05 19	12	310	6144	0.83
G	151	1035		*	ZAGREB	84 02 26	- 84 11 02	18	252	4656	0.77
G	163	0201	X	*	BRUXELLES	74 06 01	- 74 08 14	9	74	1296	0.73
G	163	2847		*	MIZUSAWA	74 09 26	- 75 08 24	29	334	5424	0.68
G	703	6084			DENVER	68 09 24	-				
G	703	6198			SIOUX FALLS	70 01 06	- 70 06 24	8	169	3384	0.83
G	703	2616			DA TONG	81 02 23	- 84 08 13	31	902	20774	0.96
G	703	2617			BAIJIATUAN	84 10 18	- 85 03 02	1	136	3170	0.97
G	703	2624			ZHANGJIAKOU	86 11 21	- 91 09 10	52	1755	38891	0.92
G	710	6020			POINT ARENA	67 12 29	-				
G	710	6060			EPHRAIM	68 12 19	-				
G	710	6202			LEONARD	70 01 02	- 70 08 17	4	228	3168	0.58
G	710	2622			BEIDAIHE	81 04 20	- 84 08 18	56	1217	26717	0.91
G	710	2617			BAIJIATUAN	84 11 10	- 85 03 02	3	113	2618	0.97
G	710	2622			BEIDAIHE	86 11 26	- 91 02 12	79	1572	32189	0.85

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Instr.			Station	Epoch	g	d	r	e
G	718		6310 URBANA	68 05 09 -				
G	718		6095 DEVILS LAKE	70 02 13 - 70 08 06	2	174	4080	0.98
G	718		2624 ZHANGJIAKOU	81 05 23 - 84 08 07	5	1173	27970	0.99
G	718		2617 BAIJIATUAN	84 10 18 - 85 03 02	4	136	3170	0.97
G	721		6399 CARLISLE	68 03 01 -				
G	721		6200 MANHATTAN	68 09 06 -				
G	721		0201 X * BRUXELLES	70 08 23 - 70 12 11	1	109	2544	0.97
G	721		0105 * CAMBRIDGE	70 12 19 - 71 03 01	3	74	3072	0.87
G	721		0101 * BIDSTON	71 07 77 - 72 02 07	10	214	9264	0.90
G	721		0201 X * BRUXELLES	72 08 19 - 72 10 20	1	63	1248	0.83
G	721		0110 * HERSTMONCEUX	72 10 26 - 73 03 03	5	131	2640	0.85
G	721		0306 STRASBOURG 2	73 03 10 - 73 06 01		0		0.00
G	721		0201 X * BRUXELLES	73 06 09 - 73 09 03	3	87	1824	0.87
G	721		0695 D * GRAZ	73 09 10 - 74 03 02	3	175	3984	0.95
G	721		0509 * TRIESTE	74 03 10 - 74 07 11	4	125	2996	0.83
G	721		0201 X * BRUXELLES	74 11 17 - 75 05 08	8	173	3384	0.82
G	721		2618 BAODI	81 03 14 - 84 05 14	3	793	18870	0.99
G	721		2617 BAIJIATUAN	84 10 21 - 85 02 11	4	114	2643	0.97
G	721		2618 BAODI	85 02 15 - 93 01 13	23	2890	66166	0.95
G	725		6405 NEW YORK	68 01 03 -				
G	728		6320 OXFORD	68 05 10 -				
G	728		6102 WACO	70 02 01 - 70 04 14	1	72	1632	0.83
G	728		2621 CHENGDE	81 04 23 - 84 08 07	30	1203	27251	0.94
G	728		2617 BAIJIATUAN	84 10 20 - 85 03 02	3	134	3119	0.97
G	728		2621 CHENGDE	86 08 25 - 93 01 15	103	2336	48290	0.86
G	730		6050 RENO	68 06 01 -				
G	730		0201 X * BRUXELLES	70 08 12 - 70 09 13	0	80	1920	1.00
G	730		0300 * STRASBOURG 1	70 09 18 - 70 12 03	0	78	2684	0.72
G	730		0516 * TORINO	70 12 12 - 71 04 12	8	124	2184	0.74
G	730		0508 * PADOVA	71 04 25 - 71 06 19	4	57	816	0.59
G	730		0201 X * BRUXELLES	72 05 09 - 72 07 17	0	70	1680	1.00
G	730		0219 D * OOSTENDE	72 08 26 - 73 01 10	10	139	4896	0.73
G	730		0220 D * BRUGGE	73 01 28 - 73 04 17	8	81	1340	0.68
G	730		0201 X * BRUXELLES	73 04 22 - 73 06 05	1	44	936	0.89
G	730		0821 * FAEROE	73 06 18 - 73 12 16	2	183	4272	0.95
G	730		0822 * AARHUS	74 01 17 - 74 05 20	3	125	2832	0.94
G	730		0201 X * BRUXELLES	74 06 02 - 74 07 22	1	52	1200	0.96
G	730		0010 * GODHAVN	74 08 09 - 76 06 20	32	683	11952	0.73
G	730		0011 * NARSSAQ	76 07 20 - 77 01 04	14	170	3264	0.80
G	735		6330 H BLACKSBURG	67 10 04 - 68 01 08	0	98	2352	1.00
G	735		6330 H BLACKSBURG	69 12 16 - 70 02 14	0	62	1488	1.00
G	735		6308 H MEMPHIS	70 10 09 - 70 12 10	0	64	1536	1.00
G	735		6330 H BLACKSBURG	71 07 22 - 72 03 12	2	233	-	-
G	735		6295 * BAY S.LOUIS	77 06 03 - 77 09 17	0	108	2592	1.00
G	761		6328 H COLUMBIA	70 03 13 - 70 06 01	0	82	1968	1.00
G	761		6326 H HUNTINGTON	70 07 05 - 70 09 29	0	88	2112	1.00
G	761		6312 H TUSCALOOSA	70 10 13 - 71 01 03	0	84	2016	1.00
G	761		6330 H BLACKSBURG	71 01 11 - 71 03 10	0	60	1440	1.00
G	761		0883 HELSINKI 2	71 11 01 - 72 03 05	5	127	2784	0.91

Directory of Gravimeters in use for Earth Tide Measurements

Instr.				Station	Epoch	g	d	r	e
G	761	0885		OULU	72 03 27 - 72 06 24	2	91	1680	0.77
G	761	0886	*	KEVO	72 08 03 - 72 12 18	1	140	3312	0.99
G	761	0887	D *	SODANKYLA	72 12 22 - 73 05 03	0	134	3216	1.00
G	761	0201	X *	BRUXELLES	73 06 06 - 73 09 14	7	102	4512	0.92
G	761	0883		HELSINKI 2	73 09 25 - 73 12 27	7	95	1776	0.78
G	761	0888	*	VAASA	74 02 02 - 74 05 21	0	110	2640	1.00
G	761	0889	*	JOENSUU	74 07 03 - 74 10 29	0	120	2880	1.00
G	761	0890	*	VAAJAKOSKI	74 11 24 - 75 03 02	3	119	2352	0.83
G	761	0883		HELSINKI 2	75 04 01 - 75 04 29	0	30	720	1.00
G	761	0844	*	TRONDHEIM	75 05 09 - 75 08 30	3	115	1536	0.56
G	761	0866	D *	KRAMFORS	75 09 11 - 76 01 17	2	131	3024	0.97
G	761	0867	*	GAVLE	76 01 23 - 76 06 02	3	134	3024	0.94
G	761	0868	*	VIVATTNET	76 06 19 - 76 10 15	7	121	2208	0.76
G	761	0869	*	BOXHOLM	76 11 12 - 77 02 21	1	103	2208	0.89
G	761	0201	X *	BRUXELLES	77 04 09 - 77 09 04	6	118	2832	0.50
G	761	0888	*	VAASA	77 09 17 - 77 12 17	1	94	2016	0.90
G	761	0883	*	HELSINKI 2	79 03 03 - 80 03 17	8	383	8400	0.92
G	761	0885	*	OULU	80 04 16 - 80 10 17	6	186	4176	0.94
G	761	0887	*	SODANKYLA	80 10 27 - 81 04 17	9	175	3504	0.84
G	765	0201	X *	BRUXELLES	75 09 14 - 76 03 27	13	194	4080	0.88
G	765	2551	*	PENANG	76 04 09 - 76 10 27	13	203	3600	0.74
G	765	2550	*	KUALA LUMPUR	76 11 11 - 77 04 25	5	167	3744	0.93
G	765	2555	*	KOTA KINABALU	77 04 30 - 77 11 11	19	197	3552	0.75
G	765	2460	*	COLOMBO	77 11 20 - 78 05 05	7	168	3744	0.93
G	765	2352	*	PESHAWAR	78 06 22 - 79 02 12	21	236	4176	0.74
G	765	0201	X *	BRUXELLES	79 05 18 - 79 08 19	1	94	2208	0.98
G	765	2603	*	BEIJING	79 10 01 - 80 03 15	4	168	3792	0.94
G	765	2605	*	LANZHOU	80 03 24 - 81 05 17	2	421	9648	0.95
G	765	2607	*	WUHAN	81 05 29 - 82 05 13	5	351	8160	0.97
G	765	0201	X *	BRUXELLES	82 06 09 - 82 11 17	11	163	3360	0.86
G	765	2450	*	KATHMANDU	82 12 08 - 83 06 10		0	0	0.00
G	765	0201	X *	BRUXELLES	83 07 14 - 84 01 09	13	181	2928	0.67
G	765	3221	*	LAMTO	84 01 26 - 84 06 18	4	146	3264	0.93
G	765	3325	*	OUAGADOUGOU	84 07 07 - 84 11 24	9	143	2688	0.78
G	765	3410	*	BANGUI	85 01 25 - 85 06 13	1	140	3264	0.97
G	765	0201	X *	BRUXELLES	86 01 23 - 86 07 09	5	169	3792	0.93
G	765	0518	*	LARDERELLO	86 08 21 - 87 06 29	9	313	7056	0.94
G	765	0201	X *	BRUXELLES	87 07 14 - 88 02 25	9	227	4848	0.89
G	765	7810	*	TANDIL	88 03 26 - 88 09 06	3	166	3840	0.97
G	765	7812	*	PILAR	88 10 01 - 88 12 02	2	64	1296	0.39
G	765	7813	*	CORRIENTES	89 03 18 - 89 10 07	6	205	1776	0.36
G	765	7815	*	S.LORENZO	89 10 16 - 90 03 13	4	151	3360	0.93
G	765	7816	*	BARILOCHE	90 03 25 - 90 08 26	4	201	4320	0.90
G	765	7805	*	BUENOS AIRES	90 10 16 - 91 05 21	3	219	5136	0.98
G	765	7819	*	SANTA ROSA	91 05 30 - 91 12 27	10	212	4560	0.90
G	783	0201	X *	BRUXELLES	77 05 19 - 77 10 25	3	159	3360	0.88
G	783	2000	*	ISTANBUL	77 11 20 - 78 05 31	12	194	3696	0.79
G	783	2001	*	ANKARA	78 06 08 - 79 05 13	15	350	5040	0.60
G	783	0201	X *	BRUXELLES	79 07 14 - 79 08 25	1	43	600	0.58

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Instr.			Station		Epoch	g	d	r	e
G	783	2607	*	WUHAN	79 10 09 - 80 03 07	0	152	3648	1.00
G	783	2600	*	GUANGZHOU	80 03 16 - 80 09 18	4	188	4272	0.95
G	783	2607	*	WUHAN	80 10 02 - 81 05 07	8	219	4656	0.89
G	783	2612	*	SHANGHAI ZO SE	81 05 30 - 82 04 24	9	331	7248	0.91
G	783	2877	*	TOKYO	82 05 09 - 82 10 25	10	171	3408	0.83
G	783	2823	*	KYOTO	82 11 06 - 83 05 21	7	198	4272	0.90
G	783	0201	X *	BRUXELLES	83 06 19 - 83 10 09	1	114	2688	0.98
G	783	7305	*	CURITIBA	83 10 31 - 84 04 25	8	174	3792	0.91
G	783	7310	*	GOIANIA	84 05 04 - 84 11 17	8	199	3792	0.79
G	783	7309	*	CUIABA	84 11 25 - 85 07 07	7	225	2208	0.41
G	783	7316	*	BELEM	85 07 26 - 86 02 07	9	199	4080	0.86
G	783	7313	*	TERESINA	86 07 30 - 87 06 21	17	327	5644	0.72
G	783	7314	*	VASSOURAS	87 06 29 - 88 06 10	19	348	4320	0.52
G	783	0201	X *	BRUXELLES	88 06 24 - 88 10 30	3	129	2784	0.90
G	783	7281	*	KOUROU	88 11 18 - 89 05 10	3	176	4080	0.97
G	783	6911	*	MARTINIQUE	89 05 21 - 89 10 29	3	163	3696	0.94
G	783	7119	*	GUAYABO	89 11 13 - 90 02 25	2	106	1920	0.75
G	783	7105	*	GUATEMALA	90 03 08 - 90 08 15	6	162	3504	0.90
G	783	7351	*	F.NORONHA	91 02 11 - 91 09 15	7	218	3312	0.63
G	783	7303	*	SAO PAULO	91 09 22 - 92 03 25	5	187	4032	0.90
G	783	7305	*	CURITIBA	92 04 03 - 92 10 02	5	184	4176	0.95
G	783	7318	*	MEDIANEIRA	93 07 23 - 93 08 16	1	26	528	0.86
G	786	6330	H	BLACKSBURG	70 02 11 - 70 03 07	0	76	1824	1.00
G	786	6338	H	DURHAM	70 03 19 - 70 06 01	0	76	1824	1.00
G	786	6330	H	BLACKSBURG	70 07 31 - 70 10 03	0	66	1584	1.00
G	786	6205	H	RUSTON	70 10 11 - 71 01 03	0	86	2064	1.00
G	786	6803	*	OTTAWA	73 05 02 - 74 12 31	7	610	13584	0.93
G	804	6331	*	FAIRFAX	69 02 06 - 70 02 03	0	364	8736	1.00
G	804	0201	X *	BRUXELLES	70 08 12 - 70 09 13	0	31	744	1.00
G	804	0256	X *	WALFERDANGE	70 09 17 - 70 12 01	2	78	1680	0.90
G	804	0508		PADOVA	70 12 05 - 71 08 15		0		0.00
G	804	0201	X *	BRUXELLES	71 11 11 - 72 03 07	5	117	2232	0.79
G	804	0610	*	CHUR	72 03 14 - 72 07 20	0	130	3120	1.00
G	804	0201	X *	BRUXELLES	72 07 28 - 72 08 20	1	23	-	-
G	804	0310	*	CLERMONT FERRAND	72 08 85 - 72 12 05	3	105	2256	0.90
G	804	0311	*	GRASSE	72 12 10 - 73 04 07	7	120	2304	0.80
G	804	0312	*	BORDEAUX	73 04 12 - 73 07 24	9	105	2016	0.80
G	804	0201	X *	BRUXELLES	73 08 02 - 73 11 09	4	101	2064	0.85
G	804	2402	D *	HYDERABAD	73 12 11 - 74 08 29	20	263	3168	0.50
G	804	2401	*	NEW DELHI	74 11 11 - 75 03 30	7	141	1584	0.47
G	804	2617		BAIJIATUAN	81 05 02 - 90 08 08	31	3386	80414	0.99
G	804	2617		BAIJIATUAN	90 08 09 - 90 09 11				
G	804	2617		BAIJIATUAN	90 09 12 - 93 05 24	3	986	23374	0.99
G	826	6330	H	BLACKSBURG	70 02 11 - 70 03 07	0	26	624	1.00
G	826	6322	H	ATLANTA	70 03 25 - 70 04 24	0	42	1008	1.00
G	826	6309	H	KNOXVILLE	70 07 20 - 70 09 20	0	64	1536	1.00
G	826	6302	H	JACKSON	70 10 12 - 71 01 02	0	84	2016	1.00
G	826	6330	H	BLACKSBURG	71 01 24 - 71 10 12	3			
G	826	6330	X *	BLACKSBURG	85 01 02 - 85 06 29	0	180	4320	1.00

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Instr.			Station	Epoch	g	d	r	e
G	826		0801	* BURKFELL/HEKLA	90 08 12 - 91 01 06	3	149	2640	0.74
G	832		2603	BEIJING	81 03 -				
G	832		2620	WENAN	81 03 31 - 83 04 12	25	743	17390	0.98
G	832		2617	BAIJIATUAN	84 10 18 - 85 02 18	2	123	2877	0.98
G	832		2649	TAINJIN	86 05 08 - 88 07 26	8	810	19302	0.99
G	832		2649	TAINJIN	88 07 26 - 89 04 12				
G	832		2649	TAINJIN	89 04 12 - 93 05 04	21	1484	31089	0.91
G	834		2639	WAN XIAN	81 03 22 - 84 07 23	24	1220	28846	0.99
G	834		2617	BAIJIATUAN	84 10 21 - 85 03 02	2	133	3098	0.97
G	834		2639	WAN XIAN	86 01 11 - 91 04 26	46	1933	44736	0.96
GWRT	1		0734	* BAD HOMBURG	81 08 01 - 84 05 01	0	1004	24096	1.00
GWRT	1		6350	RICHMOND	89 10 -				
GWRT	1		6350	RICHMOND	89 12 -				
GWRT	3		0200	* BRUXELLES	82 06 03 - 89 12 30	1	2769	65712	0.99
GWRT	4		2607	* WUHAN	85 11 24 - 88 08 24	4	1006	23808	0.99
GWRT	4		2607	* WUHAN	88 11 17 - 91 11 19	28	1099	23616	0.89
GWRT	5		0306	* STRASBOURG 2	87 10 01 - 91 03 12	0	1254	30177	1.00
GWRT	6		0731	WETTZEL	90				
GWRT	7		2849	ESASHI	88 04 - 89 03		720		
GWRT	8		0742	ASSE SALT MINE	89 04 27 - 91 05 31		672		
GWRT	9		2823	KYOTO	88 07 30 - 93 04	1	1350	19930	0.62
GWRT	10		2823	KYOTO	88 07 30 - 91 04	0	1720	41280	1.00
GWRT	11		2885	KAKIOKA	89 11 - 93 04 30	3	1276	30384	0.99
GWRT	12		6802	OTTAWA/CANTLEY	89 11 07 -				
GWRT	15		0515	* BRASIMONE	92 08 02 - 92 12 30	4	153	3456	0.94
GWRT	16		9960	SYOWA	93 03 19 -				
GWRT	17		1051	THESSALONIKI	93 01 -				
GWRT	18		0765	* POTSDAM	92 06 30 - 93 04 01	0	274	6576	1.00
GWRT	101		0734	BAD HOMBURG	86 03 22 - 88 12 27			24272	
GWRT	103		0734	BAD HOMBURG					
L	1		6100	AUSTIN	60 01 20 - 62 07 23	5	915	6624	0.30
L	2		6003	H * HONOLULU	56 10 15 - 56 11 20	0	38	912	1.00
L	2		6021	H * GLENDORA	57 05 29 - 57 07 06	0	40	960	1.00
L	2		6001	H * WAKE	57 07 29 - 57 09 01	0	36	864	1.00
L	2		4010	H * BAGUIO	57 09 20 - 57 10 30	0	42	1008	1.00
L	2		2701	H * SAIGON	57 11 24 - 57 12 30	0	38	912	1.00
L	2		2401	NEW DELHI	58 01 14 - 58 02 13	0	32	768	1.00
L	2		3421	H * BUNIA	58 03 03 - 58 04 04	0	34	816	1.00
L	2		0101	H * BIDSTON	58 07 16 - 58 09 10	0	58	1392	1.00
L	3		0201	X * BRUXELLES	73 07 25 - 73 11 04	4	102	2256	0.92
L	3		4011	* MANILA	73 11 22 - 74 04 12	11	143	2064	0.60
L	3		2601	* HONG KONG	74 04 20 - 74 09 09	9	143	2640	0.77
L	3		4160	* PORT MORESBY	74 09 22 - 75 03 16	13	176	3504	0.83
L	3		4206	* CANBERRA	75 04 01 - 75 06 27	4	88	1872	0.88
L	3		4208	* BROKEN HILL	75 07 09 - 75 11 16	11	132	2064	0.65
L	3		4207	* CHARTERS T.	75 12 14 - 76 05 03	12	142	2736	0.80
L	3		4206	* CANBERRA	76 06 05 - 76 11 07	12	157	2880	0.76
L	3		0201	X * BRUXELLES	76 12 09 - 77 03 20	10	99	1728	0.73
L	3		0201	X * BRUXELLES	77 11 16 - 78 05 17	9	183	2352	0.53

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Instr.			Station	Epoch	g	d	r	e
L	3	0201	X * BRUXELLES	78 01 14 - 78 10 22	10	283	4368	0.64
L	3	3001	* ASSOUAN	78 11 07 - 79 09 12	12	308	2256	0.30
L	3	3010	* KHARTOUM	79 09 18 - 80 03 04	9	169	3312	0.81
L	3	3601	* ANTANANARIVO	80 03 10 - 80 09 16	8	184	3792	0.86
L	3	3602	* NOSY BE	80 10 03 - 81 05 17	6	228	4416	0.81
L	3	3604	* TOLAGNARO	81 05 26 - 82 05 07	14	348	2688	0.32
L	3	3495	* HARARE	82 06 30 - 82 11 15	3	140	3216	0.96
L	3	3807	* STELLENBOSCH	82 11 26 - 83 05 16	2	174	4080	0.98
L	3	0201	X * BRUXELLES	83 05 29 - 83 10 10	6	136	2976	0.91
L	3	7308	D * VICOSA	83 11 03 - 84 05 04	13	186	3504	0.79
L	3	7305	* CURITIBA	84 05 23 - 84 07 20	2	60	1344	0.93
LDZ	3	0201	X * BRUXELLES	88 04 24 - 88 07 18	6	88	1536	0.73
LDZ	3	0201	X * BRUXELLES	89 08 15 - 90 06 27	25	318	6096	0.80
LZ	3	7305	* CURITIBA	84 07 29 - 84 10 27	6	92	1824	0.83
LZ	3	7307	* C.GRANDE	84 12 12 - 85 07 09	13	210	2544	0.50
LZ	3	7315	* MANAUS	85 07 19 - 86 03 08	13	234	3840	0.69
LZ	3	0201	X * BRUXELLES	87 03 06 - 87 12 03	12	273	4704	0.72
LZ	3	0199	X * BRUXELLES	88 04 20 - 89 04 24	10	372	6576	0.74
LZ	3	0551	* ETNA SERRA L.N.	91 12 29 - 92 09 09	13	257	5088	0.82
LZ	3	0552	* ETNA CENTURIPE	92 09 14 - 93 04 24	4	224	5184	0.96
L	4	6900	H * BERMUDA	57 10 31 - 57 12 16	0	48	1152	1.00
L	4	3420	H * LWIRO	58 03 07 - 58 04 06	0	32	768	1.00
L	4	0102	H * WINSFORD	58 07 03 - 58 08 12	0	42	1008	1.00
L	8	6339	* PITTSBURG NIKE	65 07 17 - 65 12 04	1	142	3360	0.99
L	8	6340	* PITTSBURG CATH	67 05 05 - 68 01 18	7	261	4896	0.78
L	8	4206	* CANBERRA 1/2	75 07 22 - 75 11 02	4	94	2304	1.00
L	8	4220	* HOBART	75 11 11 - 76 04 30	10	172	3120	0.76
L	8	4420	* LAUDER	76 07 15 - 76 11 07	6	118	2400	0.85
L	8	4400	* HAMILTON	76 11 21 - 77 04 16	8	148	3168	0.89
L	8	4475	* APIA	77 04 30 - 77 11 12	13	197	3120	0.66
L	8	2350	* QUETTA	77 11 28 - 78 06 11	12	201	1680	0.35
L	8	2351	D * LAHORE	78 06 15 - 79 02 13	11	243	1392	0.24
L	8	0201	X * BRUXELLES	79 03 30 - 79 11 01	3	218	2400	0.46
L	8	4105	* BANJAR BARU	79 11 29 - 80 06 15	6	200	4320	0.90
L	8	4115	* KUPANG	80 06 22 - 81 04 10	17	294	5616	0.80
L	8	2502	* CHIANG MAI	82 05 03 - 82 12 06	8	219	4320	0.82
L	8	0201	X * BRUXELLES	82 12 24 - 83 04 22	6	121	2400	0.83
L	8	0201	X * BRUXELLES	83 05 10 - 83 10 09	2	154	3600	0.97
L	8	7307	* C.GRANDE	83 11 13 - 84 04 09	6	150	1824	0.51
L	8	7305	* CURITIBA	84 05 26 - 84 07 22	1	59	1344	0.95
L	8	7308	D * VICOSA	86 10 09 - 87 02 20	3	137	3072	0.94
LD	8	0709	X * HANNOVER	73 05 19 - 73 07 24	8	68	1248	0.77
LDZ	8	0709	* HANNOVER	85 09 23 - 85 10 13	0	22	528	1.00
LZ	8	7305	* CURITIBA	84 07 29 - 84 11 09	6	105	1872	0.74
LZ	8	7311	* CAICO	84 12 11 - 85 07 29	9	231	4896	0.89
LZ	8	7317	* SALVADOR	85 08 06 - 86 05 16	14	285	3408	0.50
LZ	8	7308	D * VICOSA	86 08 07 - 86 10 03	3	59	816	0.58
LZ	8	0201	X * BRUXELLES	87 08 18 - 87 10 04	3	49	1008	0.87
LZ	8	3311	* M'BOUR	87 10 10 - 88 05 23	16	227	4560	0.84

Directory of Gravimeters in use for Earth Tide Measurements

Instr.					Station	Epoch	g	d	r	e
LZ	8	3112	D	*	ALGER	88 06 04 - 88 11 24	8	175	3600	0.86
LZ	8	3201		*	TAMANRASSET	89 03 12 - 90 03 05	7	361	8304	0.96
LZ	8	3102		*	IFRANE	90 07 20 - 90 10 19	5	94	1680	0.75
LZ	8	0551		*	ETNA SERRA L.N.	91 12 23 - 93 04 25	18	491	10080	0.86
LD	9	0690		*	INNSBRÜCK	78 10 25 - 78 12 28	1	66	1392	0.88
LD	9	0698		*	WIEN	79 01 23 - 82 06 02	3	1228	4656	0.16
LD	9	0952		*	TIHANY	79 05 06 - 79 07 14	2	71	1584	0.93
LD	9	0695		*	GRAZ	80 11 13 - 81 04 22	6	163	2640	0.68
LDZ	9	0698		*	WIEN	86 10 13 - 87 03 09	3	149	3456	0.97
LDZ	9	0950		*	BUDAPEST	87 11 12 - 88 07 03	8	236	5232	0.92
LDZ	14	0709		*	HANNOVER	85 05 29 - 88 07 12	0	45	1080	1.00
LDZ	14	0716			SCHILTACH	90 07 17 - 91 01 03	3	166		
L	29	2847	H		MIZUSAWA	68 08 31 - 68 10 06	0	38		
L	29	2847			MIZUSAWA	76 12 27 - 77 03 12				
L	29	2842			NOKOGIRIYAMA	77 12 25 - 78 01 02				
L	31	0201	X	*	BRUXELLES	78 09 06 - 78 10 10	3	36	624	0.72
LD	32	0201	X	*	BRUXELLES	78 07 18 - 79 08 22	25	402	4704	0.49
LD	32	0201	X	*	BRUXELLES	79 12 13 - 80 04 07	5	119	2592	0.91
LD	32	0201	X	*	BRUXELLES	80 07 24 - 80 09 02	1	42	960	0.95
LD	32	3020		*	MOGADISCIO	80 09 10 - 81 05 07	10	241	3120	0.54
LD	32	3040		*	DAR ES SALAAM	81 05 19 - 81 11 06	4	120	2496	0.87
LD	32	3500		*	MAPUTO	81 11 15 - 82 05 30	8	198	4320	0.91
LD	32	3505		*	NAMPULA	82 06 03 - 82 10 30	8	151	3216	0.89
LD	32	3801		*	JOHANNESBURG	82 11 26 - 83 05 18	11	174	3648	0.87
LD	32	0201	X	*	BRUXELLES	83 06 04 - 83 09 30	12	120	1968	0.68
LD	32	7306		*	S.MARIA	83 11 03 - 84 04 24	10	175	2640	0.63
LD	32	7305		*	CURITIBA	84 04 30 - 84 07 20	4	83	1728	0.87
LDZ	32	7305		*	CURITIBA	84 07 29 - 84 10 27	2	93	1920	0.86
LDZ	32	0199	X	*	BRUXELLES	85 03 09 - 85 06 01	3	86	1440	0.70
LDZ	32	0199	X	*	BRUXELLES	85 11 09 - 86 01 28	5	82	1392	0.71
L	34	2847	H		MIZUSAWA	68 08 31 - 68 10 06	0	38		
L	34	2877		*	TOKYO	80 03 30 - 81 11 18	11	600	7488	0.52
L	34	2856			FUJIGAWA	80 08 22 - 80 12 12				
L	34	2836			YAHIKO	80 12 09 - 81 05 08				
L	34	2832			YATSUGATAKE	81 05 09 - 81 08 26				
L	34	2883			NAGANO	82 05 24 - 82 09 07				
L	34	2884			KIRYU	82 09 08 - 83 02 09				
L	34	2887			MATSUMOTO	83 03 29 - 83 10 03				
L	44	0201	X	*	BRUXELLES	90 05 15 - 90 11 20	9	192	3120	0.68
LD	58	2870			SHIZUOKA	84 04 05 - 92 06 15		2990	69600	0.97
LD	59	0201	X	*	BRUXELLES	82 02 17 - 82 10 10	7	237	5184	0.91
LDZ	63	2879			FUKUSHIMA	84 10 02 - 85 02 14				
LDZ	63	2877			TOKYO	86 05 11 - 86 08 22				
LZ	79	0709		*	HANNOVER	92 07 02 - 92 10 25	0	116	2784	1.00
L	84	2403	H	*	DEHRA DUN	73 04 06 - 73 07 03	0	90	2160	1.00
LZ	87	0709		*	HANNOVER	92 04 16 - 92 10 18	4	158		
L	98	0706		*	FRANKFURT	67 11 25 - 75 01 08	38	2603	54240	0.87
L	98	0715			KIEL	74 11 10 - 74 12 10				
L	98	0735			MUNSTER	74 12 11 - 75 01 10				

Directory of Gravimeters in use for Earth Tide Measurements

Instr.			Station	Epoch	g	d	r	e
LZ	99	7305	* CURITIBA	85 08 23 - 85 12 07	8	109	2016	0.77
LZ	99	9910	* C.FERRAZ/K.G.	86 02 26 - 87 12 10	44	654	10560	0.67
LDZ	126	0201	X * BRUXELLES	86 12 19 - 87 03 26	2	100	2112	0.88
LZ	156	0705	* KARLSRUHE	87 12 12 - 88 01 13	0	34	816	1.00
LZ	156	0716	* SCHILTACH	88 12 08 - 89 04 09	2	124	1824	0.62
LZ	156	0705	* KARLSRUHE	91 07 03 - 91 10 01	0	92	2208	1.00
LZ	156	0765	* POTSDAM	91 12 05 - 92 03 30	0	114	2736	1.00
L	179	4420	* LAUDER	76 06 20 - 76 11 06	7	141	1344	0.40
L	179	4401	* TAUPO	76 12 01 - 77 03 10	3	101	2016	0.84
L	179	4402	RUAPEHU	77 04 08 - 77 04 29	1	20		
L	179	6004	UWEKAHUNA	78 02 09 - 78 03 06	2	27	576	-
L	179	4405	* WELLINGTON	81 06 06 - 82 01 18	7	228	4320	0.79
L	195	0733	DARMSTADT			24		
L	195	0737	MUENCHEN			84		
L	195	0695	H GRAZ	73		52		
LZ	249	0705	* KARLSRUHE	87 12 12 - 88 01 13	0	34	816	1.00
LZ	249	0716	* SCHILTACH	88 12 09 - 89 04 10	1	124	2880	0.97
LZ	249	0705	* KARLSRUHE	91 07 02 - 91 10 03	0	94	2256	1.00
LZ	249	0765	* POTSDAM	91 12 05 - 92 03 30	0	114	2736	1.00
L	250	0717	D FURSTENFELDBRUCK	71 03 09 - 71 05 21	1	68	1632	
L	258	0201	X * BRUXELLES	71 08 03 - 71 10 11	1	71	1680	0.99
L	258	0256	X * WALFERDANGE	72 02 10 - 72 03 23	1	44	816	0.77
L	258	0883	HELSINKI 2	72 05 15 - 72 09 08				
L	258	0695	H GRAZ	73 06 05 - 73 07 17		60		
L	258	0480	PORTO	74 07 14 - 74 09 14	3	52		
L	260	0709	X * HANNOVER	72 12 23 - 74 02 20	16	426	5040	0.49
LZ	265	1051	THESSALONIKI	90 10 30 - 91 06 09	4	164		
L	298	0201	X * BRUXELLES	73 03 15 - 73 07 28	4	137	3096	0.94
L	298	0709	X * HANNOVER	73 09 20 - 80 05 01	4	2418	10464	0.18
L	298	0800	* LAUGASKOLI	75 07 05 - 75 08 20		47		
L	298	0701	BONN	75 10 13 - 76 03 19	1	155		
L	298	7202	MARACAIBO	78 06 - 78 11			3612	
L	298	7203	D LLANO DEL HATO	78 12 - 79 02			1344	
LZ	299	0709	X * HANNOVER	73 05 30 - 73 07 29	0	64	1488	1.00
LZ	299	0705	KARLSRUHE	91 10 15 - 91 11 19	1	32		
LZ	299	0709	* HANNOVER	92 06 30 - 92 10 12	0	95	2280	1.00
LZ	299	0705	KARLSRUHE	92 11 26 - 93 03 01	0	95	2280	1.00
L	301	0410	* TOLEDO	78 03 19 - 78 07 18	9	124	2496	0.84
L	301	0401	* VALLE D.L.CAIDOS	78 07 28 - 78 09 14	2	50	1104	0.93
L	301	0401	* VALLE D.L.CAIDOS	78 09 21 - 79 01 29	7	132	2544	0.80
L	301	0427	* SANTIAGO	79 02 27 - 79 10 03	6	220	4416	0.84
L	301	0409	* CUBILLOS	79 10 08 - 80 04 05	5	183	3408	0.78
L	301	0413	* CIUDAD REAL	80 04 22 - 80 09 30	4	163	3360	0.86
L	301	0403	* GRANADA	80 11 26 - 81 03 14	3	110	2496	0.95
L	301	0414	* LA GRANJA	81 05 06 - 81 11 02	7	182	3552	0.81
L	301	0411	* BARCELONA	81 11 27 - 82 05 26	7	182	3600	0.83
L	301	0407	* SEPULVEDA	82 08 04 - 82 11 04	4	94	1872	0.83
L	301	0433	* CALATAYUD	82 12 11 - 83 07 14	5	217	4800	0.92
L	304	2847	MIZUSAWA	76 12 27 - 77 03 12				

Directory of Gravimeters in use for Earth Tide Measurements

Instr.			Station	Epoch	g	d	r	e
L	305	2847	MIZUSAWA	73 09 13 - 73 09 28				
L	305	2848	AKAGANE	74 03 09 - 74 04 06	2	26	-	-
L	305	0201	X * BRUXELLES	74 05 25 - 75 11 04	5	530	4320	0.34
L	305	0315	SEVRES BIPM	74 08 04 - 74 09 03	2	30	576	0.80
L	305	2847	* MIZUSAWA	74 09 17 - 76 03 30	10	562	7584	0.56
L	305	2847	MIZUSAWA	75 11 11 - 76 03 30		74		
L	305	2847	MIZUSAWA	76 12 27 - 77 03 12		38		
L	305	4011	MANILA	77 11 03 - 77 12 17	0	46	1104	1.00
L	305	4010	* BAGUIO	77 12 21 - 78 02 03	0	46	1104	1.00
L	308	2847	MIZUSAWA	76 12 27 - 77 03 12				
L	318	0750	D * BERLIN	78 03 29 - 79 05 05	2	404	8880	0.92
LZ	318	0765	* POTSDAM	91 02 09 - 93 04 07	7	789	17760	0.94
L	336	0201	X * BRUXELLES	73 11 09 - 74 05 09	15	174	3456	0.83
L	336	0315	X SEVRES BIPM	74 08 04 - 74 09 03	3	30	648	0.90
L	336	3000	D * CAIRO/HELWAN	74 09 26 - 75 01 24	12	122	1440	0.49
L	336	4206	* CANBERRA	75 03 30 - 75 06 27	1	89	2112	0.99
L	336	4211	* PERTH/MUNDARING	75 07 11 - 75 11 10	6	122	2352	0.80
L	336	4210	* DARWIN	75 11 12 - 76 04 02	5	133	2688	0.84
L	336	4100	* BANDUNG	76 04 11 - 76 11 10	11	215	4704	0.91
L	336	4110	* UJUNG PANDANG	76 11 21 - 77 04 12	8	144	3072	0.89
L	336	4150	* JAYA PURA	77 04 24 - 78 01 01	4	254	1968	0.32
L	336	0201	X * BRUXELLES	78 03 12 - 78 06 18	5	69	1296	0.78
L	336	4111	* MANADO	78 07 25 - 78 12 16	12	145	2688	0.77
L	336	0201	X * BRUXELLES	79 01 28 - 79 11 13	8	289	3552	0.51
L	336	3030	* NAIROBI	80 01 18 - 80 10 21	7	279	4944	0.74
L	336	3031	* VOI	80 12 24 - 81 04 25	5	125	2592	0.86
L	336	3014	* ADDIS ABABA	81 05 06 - 81 10 28	6	174	3792	0.90
L	336	3018	* ARTA DJIBOUTI	81 10 31 - 82 05 05	2	188	4416	0.98
L	336	3451	* BUTARE	82 05 15 - 82 11 08	10	179	3374	0.79
L	336	0201	X * BRUXELLES	82 11 27 - 83 03 22	4	117	2544	0.91
L	336	0325	* AVIGNON	83 03 31 - 83 09 25	9	180	3840	0.89
LZ	336	0201	X * BRUXELLES	83 10 20 - 84 01 11	6	85	1776	0.87
LZ	336	3400	* NIAMEY	84 01 26 - 84 06 05	15	133	2208	0.69
LZ	336	3399	* ARLIT	84 06 16 - 84 10 30	10	138	1920	0.58
LZ	336	3410	* BANGUI	85 02 01 - 85 10 27	6	269	5952	0.92
LZ	336	3415	* BRAZZAVILLE	85 12 06 - 86 06 04	4	182	4128	0.95
LZ	336	0201	X * BRUXELLES	86 07 23 - 87 01 08	8	170	3408	0.84
LZ	336	0199	X * BRUXELLES	86 07 23 - 87 06 03	17	317	6288	0.83
LZ	336	3312	* KEDOUGOU	87 10 24 - 88 05 14	10	205	3552	0.72
LZ	336	3401	* BAMAKO	88 06 01 - 88 10 27	3	150	3504	0.97
LZ	336	3300	* NOUAKCHOTT	89 03 06 - 89 07 19	7	137	2880	0.88
LZ	336	0201	X * BRUXELLES	89 08 11 - 90 02 12	16	187	3216	0.72
LZ	336	3090	* LANZAROTE 1	90 04 14 - 91 02 21	18	315	6480	0.86
LZ	336	3091	* LANZAROTE 2	91 02 26 - 93 02 06	11	204	4368	0.89
LZ	336	3092	* LANZ.TIMANFAYA	93 02 07 - 93 07 23	6	168	3792	0.94
L	375	2840	ABURATSUBO	77 12 23 - 78 01 13				
LZ	380	0711	BERCHTESGADEN	78 04 27 - 78 06 05	0	40	960	1.00
L	398	4206	* CANBERRA	76 07 29 - 76 10 29	7	94	1728	0.77
L	402	0201	X * BRUXELLES	76 03 05 - 76 05 15	5	67	1344	0.84

Directory of Gravimeters in use for Earth Tide Measurements

Instr.		Station			Epoch	g	d	r	e
L	402	4450		*	NOUMEA	76 06 23 - 76 11 03	12	136	2256	0.69
L	402	4460		*	SUVA FIJI	76 11 18 - 77 04 19	10	153	2304	0.63
L	402	4480		*	PAPEETE	77 05 10 - 77 10 20	9	163	3408	0.87
L	402	2201		*	TEHERAN	77 12 21 - 78 06 25	8	187	3936	0.88
L	402	2202		*	TABRIZ	78 07 01 - 79 06 03	24	338	6864	0.85
L	402	0201	X	*	BRUXELLES	79 06 24 - 79 08 26	3	66	1200	0.76
L	402	2607		*	WUHAN	79 10 11 - 80 03 06	3	148	3408	0.96
L	402	2604		*	KUNMING	80 03 18 - 81 05 27	8	436	9024	0.86
L	402	2847		*	MIZUSAWA	81 06 10 - 81 11 11	7	156	3456	0.92
L	402	2897		*	MEMAMBETSU	81 11 17 - 82 04 24	8	160	3504	0.91
L	402	2875		*	KANOYA	82 05 12 - 82 11 04	17	178	2928	0.69
L	402	2450		*	KATHMANDU	82 12 08 - 83 03 20		0	0	0.00
L	402	2450		*	KATHMANDU	83 03 27 - 83 11 18	11	238	4032	0.71
LZ	402	0201	X	*	BRUXELLES	84 01 03 - 84 03 18	3	77	1632	0.88
LZ	402	0886		*	KEVO	84 04 02 - 84 09 11	6	165	3504	0.88
LZ	402	0402		*	MADRID	84 09 30 - 85 02 28	2	153	3600	0.98
LZ	402	7408		*	AREQUIPA	85 03 20 - 85 10 08	9	203	4464	0.92
LZ	402	7410		*	CHICLAYO	85 11 04 - 86 03 24	11	142	2544	0.75
LZ	402	7500		*	LA PAZ	86 05 11 - 86 11 02	2	177	4176	0.98
LZ	402	7506		*	SANTA CRUZ 2	86 11 19 - 86 12 2	1	34	768	0.94
LZ	402	7450		*	QUITO	87 04 24 - 87 09 30	9	161	3264	0.85
LZ	402	7250		*	BOGOTA	87 11 21 - 88 04 20	14	152	2640	0.73
LZ	402	7254		*	CALI	88 05 30 - 88 07 31	2	64	1344	0.88
LZ	402	7201		*	CARACAS	88 12 02 - 89 03 09	3	99	2112	0.89
LZ	402	6975		*	TRINIDAD	89 05 25 - 89 09 26	4	126	2736	0.91
LZ	402	7118		*	SAN JOSE	89 11 14 - 90 03 02	5	110	2304	0.88
LZ	402	7002		*	MEXICO	90 03 16 - 91 02 21	13	345	2592	0.31
LZ	402	0201	X	*	BRUXELLES	91 09 19 - 92 05 11	12	237	4848	0.85
LZ	402	7601		*	IQUIQUE	92 11 15 - 93 02 23	3	102	2256	0.92
L	434	0404		*	SANTANDER	77 02 07 - 77 06 17	7	132	2832	0.89
L	434	0406		*	S.FERNANDO	77 12 11 - 78 03 03	7	84	1680	0.83
L	434	0201	X	*	BRUXELLES	78 03 15 - 78 09 25	9	196	3792	0.81
L	434	0401		*	VALLE D.L.CAIDOS	79 02 08 - 79 06 11	6	125	2688	0.90
L	434	0412		*	CARBONERO	79 08 01 - 79 10 22	3	84	1872	0.93
L	434	0401		*	VALLE D.L.CAIDOS	80 01 04 - 80 04 13	0	102	2448	1.00
L	434	0417		*	ARCAS	80 04 22 - 80 10 08	10	171	3552	0.87
L	434	0402		*	MADRID	80 11 26 - 81 03 22	2	118	2736	0.97
L	434	0402		*	MADRID	81 04 03 - 81 05 27	1	56	1296	0.96
L	434	0420		*	PAMPLONA	82 02 18 - 82 11 21	10	278	5472	0.82
L	434	0419		*	PLASENCIA	83 03 06 - 83 09 05	5	185	4128	0.93
LZ	434	0402			MADRID	85 03 17 - 85 12 12	11	272	5904	0.90
LZ	434	0434		*	OVIEDO	86 10 01 - 87 03 22	11	174	3264	0.78
LZ	434	3090		*	LANZAROTE 1	87 05 15 - 91 06 12	52	1491	28416	0.79
L	447	2847			MIZUSAWA	76 12 27 - 77 03 12				
L	447	2840			ABURATSUBO	77 12 23 - 78 01 13				
L	447	2877		*	TOKYO	80 03 30 - 81 11 18	11	600	7392	0.51
L	447	2885			KAKIOKA	82 08 28 - 83 02 14				
L	447	2853			INUYAMA	83 03 15 - 83 09 09				
LZ	447	2877			TOKYO	84 01 22 - 84 03 19				

Directory of Gravimeters in use for Earth Tide Measurements

Instr.				Station	Epoch	g	d	r	e
LZ	447	2886		TAKAYAMA	84 04 25 - 84 11 28				
LZ	447	2882		KANAZAWA	85 08 30 - 85 11 23				
L	457	4011		MANILA	77 11 03 - 78 02 03	0	94	2256	1.00
LZ	457	2849	*	ESASHI	80 01 02 - 80 12 29	9	365	7872	0.90
LZ	457	2849		ESASHI	81 01 02 - 81 12 27	9	365	6616	0.76
LZ	477	9960	*	SYOWA	87 04 01 - 87 06 01	0	62	1488	1.00
L	487	0201	X *	BRUXELLES	78 05 20 - 79 03 12	12	298	2736	0.38
L	487	0201	X *	BRUXELLES	81 09 25 - 83 09 02	23	710	6816	0.00
L	487	0225	*	VEURNE	82 12 09 - 83 07 26	5	232	5328	0.96
L	487	0227	*	GISTEL	83 09 18 - 84 03 23	8	189	3936	0.87
LZ	487	0201	X *	BRUXELLES	84 03 31 - 86 02 26	25	700	6000	0.36
LZ	487	0402	*	MADRID	84 10 11 - 85 02 26	6	141	3072	0.91
LZ	487	0201	X *	BRUXELLES	86 07 16 - 86 10 18	6	96	1440	0.63
LZ	487	7312	*	P.PRUDENTE	86 11 21 - 87 05 29	8	190	4080	0.89
LZ	487	7306	*	S.MARIA	88 04 28 - 88 06 09	5	45	720	0.67
LZ	487	0201	X *	BRUXELLES	88 06 30 - 88 09 20	4	84	1632	0.81
LZ	487	0201	X *	BRUXELLES	88 09 24 - 89 01 15	6	115	2112	0.77
LZ	487	0201	X *	BRUXELLES	93 02 20 - 93 04 21	1	62	1440	0.97
LZ	584	2607		WUHAN			96	2304	
LZ	584	0201	X *	BRUXELLES	80 11 30 - 81 01 17	5	50	912	0.56
LZ	584	2633		QUANZHOU	82 04 07 - 82 07 15	2	100	2352	0.98
LZ	584	2640		HINADO	83 01 09 - 83 06 10	8	152	3312	0.91
LZ	589	0201	X *	BRUXELLES	80 12 03 - 81 01 12	1	43	960	0.91
LZ	589	2633		QUANZHOU	82 04 05 - 82 08 24	3	142	3264	0.96
LZ	589	2640		HINADO	83 01 09 - 83 05 08	8	118	2544	0.90
LZ	589	9911		GREAT WALL/K.G.	88 02 15 - 89 03 01		342		
L	600	0201	X *	BRUXELLES	85 12 03 - 86 03 22	5	111	2304	0.87
L	601	0201	X *	BRUXELLES	86 07 16 - 86 10 07	1	85	1920	0.95
L	601	0201	X *	BRUXELLES	88 06 15 - 88 09 11	2	89	1848	0.86
LZ	612	6330	*	BLACKSBURG	91 07 05 - 91 12 16	3	166	3696	0.93
L	665	0886	*	KEVO	84 03 31 - 84 09 14	2	170	3984	0.98
LZ	665	0201	X *	BRUXELLES	84 09 29 - 85 02 25	9	151	2928	0.81
LZ	665	0402		MADRID	85 03 17 - 85 12 09	4	270	6240	0.96
LZ	665	0401		VALLE D.L.CAIDOS	86 02 27 - 86 10 01	16	218	3072	0.59
LZ	665	0424	*	CADI	87 05 01 - 87 08 27	11	120	2112	0.73
L	680	2870		SHIZUOKA	84 09 03 - 93 04	1	2850	42120	0.62
LZ	709	0716		SCHILTACH	90 07 17 - 91 01 03	3	166		
LZ	805	9941	*	ASUKA	87 06 26 - 87 11 13	0	142	3408	1.00
LZ	906	0201	X *	BRUXELLES	88 01 31 - 88 05 19	5	111	2400	0.90
LZ	906	7805	*	BUENOS AIRES	88 09 26 - 89 02 27	5	156	3552	0.95
LZ	906	7895	*	TACUAREMBO	89 03 07 - 89 09 27	8	207	4368	0.88
LZ	906	7814	*	ZONDA	89 10 07 - 90 03 27	15	173	2976	0.72
LZ	906	7817	*	USHUAIA	90 04 07 - 90 09 07	7	155	3408	0.92
LZ	906	7818	*	C.RIVADAVIA	90 10 07 - 91 05 24	10	238	4608	0.81
LZ	906	0201	X *	BRUXELLES	91 06 27 - 92 04 11	14	291	5712	0.82
LZ	906	0201	X *	BRUXELLES	92 10 27 - 93 04 14	4	171	3840	0.94
LZ	913	7303	*	SAO PAULO	91 05 09 - 92 05 18	16	378	7776	0.86
LZ	913	7319	*	VALINHOS	92 10 11 - 93 05 23	12	226	4464	0.82
LZ	995	0765	*	POTSDAM	91 12 05 - 92 03 30	0	108	2592	1.00

Directory of Gravimeters in use for Earth Tide Measurements

Instr.		Station		Epoch	g	d	r	e
LZ 995	0709	*	HANNOVER/D	92 04 16 - 92 07 27	1	97		
LZ 995	0765		POTSDAM	93 01 -				
LCR/D 73	9960		SYOWA	92 02 16 - 92 12 23				
LCR/G515	9960		SYOWA	92 02 16 - 92 09 21				
NA 138	0300	*	STRASBOURG 1	64 11 02 - 67 08 09	0	1012	23328	1.00
NAB 140	0708	H	WINGST	58 01 23 - 58 04 01	2	66		
NAB 140	0711	H	BERCHTESGADEN	58 07 22 - 58 11 06	1	58		
NAB 140	0706		FRANKFURT	62 03 25 - 62 07 31		130		
NAB 140	0706	*	FRANKFURT	63 03 09 - 70 05 24	14	2635	28704	0.45
NA 167	3401	H	BAMAKO	58 08 00 - 58 09 00			1080	
NA 167	3601	H	ANTANANARIVO	59 01 00 - 59 02 00		1080		
NA 167	3410	H	BANGUI	65 06 00 - 65 07 00		45	1080	
UCSD	6350		RICHMOND	89 12				
UCSD 1	6350		RICHMOND	90 04 14 - 91 09 25				
UCSD 1	6035		FAIRBANKS	91 11 24 -				
UCSD 1	6035		FAIRBANKS	91 11 24 -				
UCSD /SG	6025		LA JOLLA	72 07 06 - 72 08 29				
UCSD/SGA	6025		LA JOLLA	72 10 03 - 73 01 12			100	
UCSD/SGA	6024	*	PINON FLAT	73 08 23 - 75 02 26	0	554	12912	0.97
UCSD/SGB	6029		FAIRBANKS/ALASKA					
UCSD/SGB	6005		KILAUEA VOLCANO	89 12 -				
WES/SAK	0315	*	SEVRES BIPM	74 05 06 - 77 07 24	43	1178	15792	0.56

DIRECTORY OF GRAVITY METERS IN USE FOR EARTH TIDE MEASUREMENTS

8 february 1994

PART II: On File according to the Stations Numbers

	INSTRUMENTS	Number of records		
A	- ASKANIA GS 11, GS 12	113		
A*	- ASKANIA GS 15	94		
A#	- ASKANIA GS 25	2		
AB	- ASKANIA modified by M. Bonatz	48		
AD	- ASKANIA modified by Dittfeld and Neumeyer	5		
AR	- ASKANIA modified by I. Rogatnev	1	=	263
G	- GEODYNAMICS	210	=	210
L	- LACOSTE ROMBERG model G	173		
LD	- LACOSTE ROMBERG model D	31		
LZ	- LACOSTE ROMBERG with zero method	112	=	316
ET	- LACOSTE ROMBERG Earth Tide/mechanical feedback	55		
ET*	- LACOSTE ROMBERG Earth Tide/electronic feedback	19	=	74
GWR	- SUPERCONDUCTING gravimeter	20		
UCSD-	SGA/B SUPERCONDUCTING gravimeter	5		
UCSD		3	=	28
	Others	2		
	NA	4		
	NAB	4		
	LCR D/G	2	=	12
		Total		903

g number of gaps
d number of days of installation
r number of hourly readings
e efficiency R/24D

H Data of historical interest only
D Data to be discarded for technical reasons
X Data replaced by more recent and more precise data

* preceding the station's name indicates that the data are on diskette in ICET library

number of * series = 525
total number of * hourly readings = 3.055.469

Directory of Gravimeters in use for Earth Tide Measurements

Instr.		Station			Epoch	g	d	r	e
A	85	0004		*	LONGYEARBYEN 69 09 03 - 70 06 06	3	278	6336	0.95
A	116	0004		*	LONGYEARBYEN 69 09 19 - 70 06 15	5	271	6240	0.96
A*	206	0004		*	LONGYEARBYEN 70 05 05 - 70 06 14	2	42	792	0.78
G	730	0010		*	GODHAVN 74 08 09 - 76 06 20	32	683	11952	0.73
G	730	0011		*	NARSSAQ 76 07 20 - 77 01 04	14	170	3264	0.80
ET*	10	0101		*	BIDSTON 84 05 26 - 84 11 24	0	184	4416	1.00
ET*	13	0101			BIDSTON	0	183		
ET	15	0101			BIDSTON	0	183		
G	721	0101		*	BIDSTON 71 07 77 - 72 02 07	10	214	9264	0.90
L	2	0101	H	*	BIDSTON 58 07 16 - 58 09 10	0	58	1392	1.00
L	4	0102	H	*	WINSFORD 58 07 03 - 58 08 12	0	42	1008	1.00
G	721	0105		*	CAMBRIDGE 70 12 19 - 71 03 01	3	74	3072	0.87
G	721	0110		*	HERSTMONCEUX 72 10 26 - 73 03 03	5	131	2640	0.85
ET	15	0111		*	LONDON 72 04 30 - 72 07 01	0	64	1536	1.00
ET	15	0112		*	TAUNTON 72 08 08 - 72 09 29	0	54	1296	1.00
ET	15	0114		*	REDRUTH 73 03 10 - 73 07 22	3	136	2208	0.68
ET	15	0116		*	NEWTOWN 75 01 13 - 75 04 02	1	81	1344	0.69
ET	10	0150		*	EDINBURGH 86 03 01 - 86 07 08	1	131	2208	0.70
LZ	3	0199	X	*	BRUXELLES 88 04 20 - 89 04 24	10	372	6576	0.74
LDZ	32	0199	X	*	BRUXELLES 85 03 09 - 85 06 01	3	86	1440	0.70
LDZ	32	0199	X	*	BRUXELLES 85 11 09 - 86 01 28	5	82	1392	0.71
LZ	336	0199	X	*	BRUXELLES 86 07 23 - 87 06 03	17	317	6288	0.83
GWRT	3	0200		*	BRUXELLES 82 06 03 - 89 12 30	1	2769	65712	0.99
A	145	0201	X	*	BRUXELLES 58 07 02 - 64 05 09	10	1438		
A	145	0201	X	*	BRUXELLES 66 06 11 - 67 06 08	1	322	7704	0.99
A	160	0201	X	*	BRUXELLES 60 04 03 - 63 03 08	3	876		
AB	160/3	0201	X	*	BRUXELLES 74 05 14 - 74 10 17	12	158	4608	0.61
A	191	0201	X	*	BRUXELLES 65 06 04 - 67 12 02	18	518		
AB	191/1	0201	X	*	BRUXELLES 74 01 17 - 74 08 21	7	219	9504	0.91
A*	206	0201	X	*	BRUXELLES 71 03 20 - 71 06 22	1	96	2256	0.98
A*	210	0201	X	*	BRUXELLES 71 08 13 - 71 12 05	3	114	3360	0.60
A*	212	0201	X	*	BRUXELLES 74 07 08 - 74 12 19	10	166	7104	0.89
A*	212	0201	X	*	BRUXELLES 78 03 18 - 78 09 26	6	194	4320	0.93
A*	226	0201	X	*	BRUXELLES 74 01 09 - 74 03 08	5	60	2304	0.80
ET*	13	0201		*	BRUXELLES 84 10 11 - 85 02 14	0	128	3072	1.00
G	74	0201	X	*	BRUXELLES 72 08 25 - 72 11 25	1	91	2088	0.96
G	74	0201	X	*	BRUXELLES 73 12 15 - 74 06 30	2	174	4176	
G	84	0201	X	*	BRUXELLES 71 07 09 - 73 11 08	35	855	16896	0.82
G	84	0201	X	*	BRUXELLES 79 01 30 - 79 07 09	12	160	3216	0.84
G	84	0201	X	*	BRUXELLES 83 06 30 - 84 07 20	15	388	7152	0.77
G	84	0201	X	*	BRUXELLES 89 06 05 - 90 07 24	14	417	8688	0.87
G	84	0201	X	*	BRUXELLES 91 10 20 - 91 11 24	1	36	816	0.93
G	84	0201	X	*	BRUXELLES 93 09 15 - 94 01 11	7	120	2160	0.75
G	151	0201	X	*	BRUXELLES 75 09 17 - 76 02 18	12	156	5952	1.59
G	163	0201	X	*	BRUXELLES 74 06 01 - 74 08 14	9	74	1296	0.73
G	721	0201	X	*	BRUXELLES 70 08 23 - 70 12 11	1	109	2544	0.97
G	721	0201	X	*	BRUXELLES 72 08 19 - 72 10 20	1	63	1248	0.83
G	721	0201	X	*	BRUXELLES 73 06 09 - 73 09 03	3	87	1824	0.87

Directory of Gravimeters in use for Earth Tide Measurements

Instr.		Station			Epoch	g	d	r	e
G	721	0201	X	* BRUXELLES	74 11 17 - 75 05 08	8	173	3384	0.82
G	730	0201	X	* BRUXELLES	70 08 12 - 70 09 13	0	80	1920	1.00
G	730	0201	X	* BRUXELLES	72 05 09 - 72 07 17	0	70	1680	1.00
G	730	0201	X	* BRUXELLES	73 04 22 - 73 06 05	1	44	936	0.89
G	730	0201	X	* BRUXELLES	74 06 02 - 74 07 22	1	52	1200	0.96
G	761	0201	X	* BRUXELLES	73 06 06 - 73 09 14	7	102	4512	0.92
G	761	0201	X	* BRUXELLES	77 04 09 - 77 09 04	6	118	2832	0.50
G	765	0201	X	* BRUXELLES	75 09 14 - 76 03 27	13	194	4080	0.88
G	765	0201	X	* BRUXELLES	79 05 18 - 79 08 19	1	94	2208	0.98
G	765	0201	X	* BRUXELLES	82 06 09 - 82 11 17	11	163	3360	0.86
G	765	0201	X	* BRUXELLES	83 07 14 - 84 01 09	13	181	2928	0.67
G	765	0201	X	* BRUXELLES	86 01 23 - 86 07 09	5	169	3792	0.93
G	765	0201	X	* BRUXELLES	87 07 14 - 88 02 25	9	227	4848	0.89
G	783	0201	X	* BRUXELLES	77 05 19 - 77 10 25	3	159	3360	0.88
G	783	0201	X	* BRUXELLES	79 07 14 - 79 08 25	1	43	600	0.58
G	783	0201	X	* BRUXELLES	83 06 19 - 83 10 09	1	114	2688	0.98
G	783	0201	X	* BRUXELLES	88 06 24 - 88 10 30	3	129	2784	0.90
G	804	0201	X	* BRUXELLES	70 08 12 - 70 09 13	0	31	744	1.00
G	804	0201	X	* BRUXELLES	71 11 11 - 72 03 07	5	117	2232	0.79
G	804	0201	X	* BRUXELLES	72 07 28 - 72 08 20	1	23	-	-
G	804	0201	X	* BRUXELLES	73 08 02 - 73 11 09	4	101	2064	0.85
L	3	0201	X	* BRUXELLES	73 07 25 - 73 11 04	4	102	2256	0.92
L	3	0201	X	* BRUXELLES	76 12 09 - 77 03 20	10	99	1728	0.73
L	3	0201	X	* BRUXELLES	77 11 16 - 78 05 17	9	183	2352	0.53
L	3	0201	X	* BRUXELLES	78 01 14 - 78 10 22	10	283	4368	0.64
L	3	0201	X	* BRUXELLES	83 05 29 - 83 10 10	6	136	2976	0.91
LDZ	3	0201	X	* BRUXELLES	88 04 24 - 88 07 18	6	88	1536	0.73
LDZ	3	0201	X	* BRUXELLES	89 08 15 - 90 06 27	25	318	6096	0.80
LZ	3	0201	X	* BRUXELLES	87 03 06 - 87 12 03	12	273	4704	0.72
L	8	0201	X	* BRUXELLES	79 03 30 - 79 11 01	3	218	2400	0.46
L	8	0201	X	* BRUXELLES	82 12 24 - 83 04 22	6	121	2400	0.83
L	8	0201	X	* BRUXELLES	83 05 10 - 83 10 09	2	154	3600	0.97
LZ	8	0201	X	* BRUXELLES	87 08 18 - 87 10 04	3	49	1008	0.87
L	31	0201	X	* BRUXELLES	78 09 06 - 78 10 10	3	36	624	0.72
LD	32	0201	X	* BRUXELLES	78 07 18 - 79 08 22	25	402	4704	0.49
LD	32	0201	X	* BRUXELLES	79 12 13 - 80 04 07	5	119	2592	0.91
LD	32	0201	X	* BRUXELLES	80 07 24 - 80 09 02	1	42	960	0.95
LD	32	0201	X	* BRUXELLES	83 06 04 - 83 09 30	12	120	1968	0.68
L	44	0201	X	* BRUXELLES	90 05 15 - 90 11 20	9	192	3120	0.68
LD	59	0201	X	* BRUXELLES	82 02 17 - 82 10 10	7	237	5184	0.91
LDZ	126	0201	X	* BRUXELLES	86 12 19 - 87 03 26	2	100	2112	0.88
L	258	0201	X	* BRUXELLES	71 08 03 - 71 10 11	1	71	1680	0.99
L	298	0201	X	* BRUXELLES	73 03 15 - 73 07 28	4	137	3096	0.94
L	305	0201	X	* BRUXELLES	74 05 25 - 75 11 04	5	530	4320	0.34
L	336	0201	X	* BRUXELLES	73 11 09 - 74 05 09	15	174	3456	0.83
L	336	0201	X	* BRUXELLES	78 03 12 - 78 06 18	5	69	1296	0.78
L	336	0201	X	* BRUXELLES	79 01 28 - 79 11 13	8	289	3552	0.51
L	336	0201	X	* BRUXELLES	82 11 27 - 83 03 22	4	117	2544	0.91
LZ	336	0201	X	* BRUXELLES	83 10 20 - 84 01 11	6	85	1776	0.87

Directory of Gravimeters in use for Earth Tide Measurements

Instr.		Station				Epoch	g	d	r	e
LZ	336	0201	X	*	BRUXELLES	86 07 23 - 87 01 08	8	170	3408	0.84
LZ	336	0201	X	*	BRUXELLES	89 08 11 - 90 02 12	16	187	3216	0.72
L	402	0201	X	*	BRUXELLES	76 03 05 - 76 05 15	5	67	1344	0.84
L	402	0201	X	*	BRUXELLES	79 06 24 - 79 08 26	3	66	1200	0.76
LZ	402	0201	X	*	BRUXELLES	84 01 03 - 84 03 18	3	77	1632	0.88
LZ	402	0201	X	*	BRUXELLES	91 09 19 - 92 05 11	12	237	4848	0.85
L	434	0201	X	*	BRUXELLES	78 03 15 - 78 09 25	9	196	3792	0.81
L	487	0201	X	*	BRUXELLES	78 05 20 - 79 03 12	12	298	2736	0.38
L	487	0201	X	*	BRUXELLES	81 09 25 - 83 09 02	23	710	6816	0.00
LZ	487	0201	X	*	BRUXELLES	84 03 31 - 86 02 26	25	700	6000	0.36
LZ	487	0201	X	*	BRUXELLES	86 07 16 - 86 10 18	6	96	1440	0.63
LZ	487	0201	X	*	BRUXELLES	88 06 30 - 88 09 20	4	84	1632	0.81
LZ	487	0201	X	*	BRUXELLES	88 09 24 - 89 01 15	6	115	2112	0.77
LZ	487	0201	X	*	BRUXELLES	93 02 20 - 93 04 21	1	62	1440	0.97
LZ	584	0201	X	*	BRUXELLES	80 11 30 - 81 01 17	5	50	912	0.56
LZ	589	0201	X	*	BRUXELLES	80 12 03 - 81 01 12	1	43	960	0.91
L	600	0201	X	*	BRUXELLES	85 12 03 - 86 03 22	5	111	2304	0.87
L	601	0201	X	*	BRUXELLES	86 07 16 - 86 10 07	1	85	1920	0.95
L	601	0201	X	*	BRUXELLES	88 06 15 - 88 09 11	2	89	1848	0.86
LZ	665	0201	X	*	BRUXELLES	84 09 29 - 85 02 25	9	151	2928	0.81
LZ	906	0201	X	*	BRUXELLES	88 01 31 - 88 05 19	5	111	2400	0.90
LZ	906	0201	X	*	BRUXELLES	91 06 27 - 92 04 11	14	291	5712	0.82
LZ	906	0201	X	*	BRUXELLES	92 10 27 - 93 04 14	4	171	3840	0.94
AB	143/15	0202		*	DOURBES	85 11 22 - 89 04 18	32	1246	25392	0.85
A	175	0212	D	*	COINTE	71 02 10 - 72 03 04	11	390	8208	0.88
A	175	0213	H		BATTICE	63 04 13 - 63 10 02	0	174		
A	175	0213	H		BATTICE	64 02 15 - 64 09 25	1	224		
G	74	0216	D		KANNE	74 11 08 - 77 10 25	19	890	21360	?
A	175	0217	H		DINANT	68 05 03 - 70 01 30	15	590		
G	730	0219	D	*	OOSTENDE	72 08 26 - 73 01 10	10	139	4896	0.73
G	730	0220	D	*	BRUGGE	73 01 28 - 73 04 17	8	81	1340	0.68
G	74	0221		*	LOUVAIN LN	82 08 07 - 83 01 08	5	156	3264	0.87
L	487	0225		*	VEURNE	82 12 09 - 83 07 26	5	232	5328	0.96
G	74	0226		*	DAMME	83 02 09 - 83 09 05	16	210	2640	0.52
L	487	0227		*	GISTEL	83 09 18 - 84 03 23	8	189	3936	0.87
A	160	0251		*	LUXEMBOURG	63 04 15 - 70 09 30	51	2086	50064	
A*	206	0256	X	*	WALFERDANGE	71 07 02 - 71 11 11	7	134	2640	0.82
G	804	0256	X	*	WALFERDANGE	70 09 17 - 70 12 01	2	78	1680	0.90
L	258	0256	X	*	WALFERDANGE	72 02 10 - 72 03 23	1	44	816	0.77
AB	145/9	0257		*	WALFERDANGE	75 10 26 - 87 12 25	199	4445	75216	0.71
AB	160/3	0257	X	*	WALFERDANGE	76 08 16 - 78 04 05	39	599	9312	0.65
AB	175/13	0257	X	*	WALFERDANGE	79 03 16 - 81 05 04	59	782	9120	0.49
AB	191/1	0257		*	WALFERDANGE	74 12 25 - 92 11 18	230	6556	121344	0.77
A#	233	0257		*	WALFERDANGE	80 12 24 - 93 01 08	107	4401	86784	0.82
G	74	0271		*	WITTEVEEN	72 12 01 - 73 03 31	3	123	2784	0.95
A*	206	0300		*	STRASBOURG 1	71 12 21 - 72 03 04	0	76	1824	1.00
G	730	0300		*	STRASBOURG 1	70 09 18 - 70 12 03	0	78	2684	0.72
NA	138	0300		*	STRASBOURG 1	64 11 02 - 67 08 09	0	1012	23328	1.00
ET	5	0306			STRASBOURG 2	73 08 06 - 79 05 03	53	2098	35184	0.70

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Instr.			Station	Epoch	g	d	r	e
ET	5	0306	STRASBOURG 2	82 06 02 - 85 06 24	16	1121	24000	0.89
G	721	0306	STRASBOURG 2	73 03 10 - 73 06 01		0		0.00
GWRT	5	0306	* STRASBOURG 2	87 10 01 - 91 03 12	0	1254	30177	1.00
G	804	0310	* CLERMONT FERRAND	72 08 85 - 72 12 05	3	105	2256	0.90
G	804	0311	* GRASSE	72 12 10 - 73 04 07	7	120	2304	0.80
G	804	0312	* BORDEAUX	73 04 12 - 73 07 24	9	105	2016	0.80
ET	16	0315	SEVRES BIPM	75 04 10 - 75 05 29	1	49	1137	0.97
L	305	0315	SEVRES BIPM	74 08 04 - 74 09 03	2	30	576	0.80
L	336	0315	X SEVRES BIPM	74 08 04 - 74 09 03	3	30	648	0.90
WES/SAK		0315	* SEVRES BIPM	74 05 06 - 77 07 24	43	1178	15792	0.56
L	336	0325	* AVIGNON	83 03 31 - 83 09 25	9	180	3840	0.89
A*	212	0401	* VALLE D.L.CAIDOS	76 08 08 - 79 05 21	24	1019	5904	0.24
A*	212	0401	* VALLE D.L.CAIDOS	80 05 01 - 82 10 19	24	903	14784	0.68
ET	15	0401	* VALLE D.L.CAIDOS	79 02 14 - 79 11 09	11	270	5184	0.80
L	301	0401	* VALLE D.L.CAIDOS	78 07 28 - 78 09 14	2	50	1104	0.93
L	301	0401	* VALLE D.L.CAIDOS	78 09 21 - 79 01 29	7	132	2544	0.80
L	434	0401	* VALLE D.L.CAIDOS	79 02 08 - 79 06 11	6	125	2688	0.90
L	434	0401	* VALLE D.L.CAIDOS	80 01 04 - 80 04 13	0	102	2448	1.00
LZ	665	0401	VALLE D.L.CAIDOS	86 02 27 - 86 10 01	16	218	3072	0.59
A*	212	0402	* MADRID	73 12 12 - 76 03 27	22	838	4272	0.21
LZ	402	0402	* MADRID	84 09 30 - 85 02 28	2	153	3600	0.98
L	434	0402	* MADRID	80 11 26 - 81 03 22	2	118	2736	0.97
L	434	0402	* MADRID	81 04 03 - 81 05 27	1	56	1296	0.96
LZ	434	0402	MADRID	85 03 17 - 85 12 12	11	272	5904	0.90
LZ	487	0402	* MADRID	84 10 11 - 85 02 26	6	141	3072	0.91
LZ	665	0402	MADRID	85 03 17 - 85 12 09	4	270	6240	0.96
A*	212	0403	D * GRANADA	76 04 03 - 76 06 20	7	81	1296	0.67
L	301	0403	* GRANADA	80 11 26 - 81 03 14	3	110	2496	0.95
L	434	0404	* SANTANDER	77 02 07 - 77 06 17	7	132	2832	0.89
A*	212	0405	* BURGOS	76 12 15 - 77 05 28	7	166	3648	0.92
L	434	0406	* S.FERNANDO	77 12 11 - 78 03 03	7	84	1680	0.83
A*	212	0407	D * SEPULVEDA	77 07 03 - 77 12 06	11	158	2736	0.72
L	301	0407	* SEPULVEDA	82 08 04 - 82 11 04	4	94	1872	0.83
L	301	0409	* CUBILLOS	79 10 08 - 80 04 05	5	183	3408	0.78
L	301	0410	* TOLEDO	78 03 19 - 78 07 18	9	124	2496	0.84
L	301	0411	* BARCELONA	81 11 27 - 82 05 26	7	182	3600	0.83
L	434	0412	* CARBONERO	79 08 01 - 79 10 22	3	84	1872	0.93
L	301	0413	* CIUDAD REAL	80 04 22 - 80 09 30	4	163	3360	0.86
L	301	0414	* LA GRANJA	81 05 06 - 81 11 02	7	182	3552	0.81
L	434	0417	* ARCAS	80 04 22 - 80 10 08	10	171	3552	0.87
L	434	0419	* PLASENCIA	83 03 06 - 83 09 05	5	185	4128	0.93
L	434	0420	* PAMPLONA	82 02 18 - 82 11 21	10	278	5472	0.82
LZ	665	0424	* CADI	87 05 01 - 87 08 27	11	120	2112	0.73
L	301	0427	* SANTIAGO	79 02 27 - 79 10 03	6	220	4416	0.84
L	301	0433	* CALATAYUD	82 12 11 - 83 07 14	5	217	4800	0.92
LZ	434	0434	* OVIEDO	86 10 01 - 87 03 22	11	174	3264	0.78
L	258	0480	PORTO	74 07 14 - 74 09 14	3	52		
A	97	0505	GENOVA	60 10 16 - 62 12 30	2	806	15336	0.79
A	108	0507	COSTOZZA	62 09 07 - 62 12 08	1	92	1440	0.65

Directory of Gravimeters in use for Earth Tide Measurements

Instr.				Station	Epoch	g	d	r	e
G	730	0508		* PADOVA	71 04 25 - 71 06 19	4	57	816	0.59
G	804	0508		PADOVA	70 12 05 - 71 08 15		0		0.00
A	108	0509		TRIESTE	59 07 02 - 60 07 09	1	374	8160	0.91
G	721	0509		* TRIESTE	74 03 10 - 74 07 11	4	125	2996	0.83
A	141	0511		RESINA	66 03 02 - 68 07 21	0	874	20976	1.00
GWRT	15	0515		* BRASIMONE	92 08 02 - 92 12 30	4	153	3456	0.94
G	730	0516		* TORINO	70 12 12 - 71 04 12	8	124	2184	0.74
G	765	0518		* LARDERELLO	86 08 21 - 87 06 29	9	313	7056	0.94
A	120	0550	H	PALERMO	63 06 29 - 63 09 25		90		
LZ	3	0551		* ETNA SERRA L.N.	91 12 29 - 92 09 09	13	257	5088	0.82
LZ	8	0551		* ETNA SERRA L.N.	91 12 23 - 93 04 25	18	491	10080	0.86
LZ	3	0552		* ETNA CENTURIPE	92 09 14 - 93 04 24	4	224	5184	0.96
ET*	13	0610		* CHUR	87 07 03 - 87 10 13	0	105	2520	1.00
G	804	0610		* CHUR	72 03 14 - 72 07 20	0	130	3120	1.00
ET*	13	0615		* ZUERICH	85 11 21 - 86 06 21	0	214	5136	1.00
ET	16	0615		ZUERICH	74 03 07 - 74 04 16	0	40	968	
ET	16	0615		ZUERICH	76 07 27 - 78 04 03			15019	
LD	9	0690		* INNSBRÜCK	78 10 25 - 78 12 28	1	66	1392	0.88
AB	190/7	0695		* GRAZ	80 07 16 - 81 05 18	7	309	7152	0.97
G	151	0695	D	* GRAZ	80 07 16 - 81 05 19	12	310	6144	0.83
G	721	0695	D	* GRAZ	73 09 10 - 74 03 02	3	175	3984	0.95
LD	9	0695		* GRAZ	80 11 13 - 81 04 22	6	163	2640	0.68
L	195	0695	H	GRAZ	73		52		
L	258	0695	H	GRAZ	73 06 05 - 73 07 17		60		
LD	9	0698		* WIEN	79 01 23 - 82 06 02	3	1228	4656	0.16
LDZ	9	0698		* WIEN	86 10 13 - 87 03 09	3	149	3456	0.97
A	85	0701		BONN	65 01 14 - 69 03 19				
AB	85/2	0701		BONN	72 12 02 - 73 03 11		101		
AB	85/2	0701		BONN	73 09 05 - 73 11 15	2	62	1476	0.99
AB	108/10	0701		BONN	75 01 11 - 75 07 06	0	177	4246	
A	116	0701		BONN	65 09 20 - 66 06 12				
A	116	0701		BONN	66 07 14 - 69 04 13			994	
AB	130/5	0701		BONN	74 06 16 - 74 09 09	6	45	1030	
AB	138/6	0701		BONN	75 02 27 - 75 07 18	0	140	3382	
AB	145/9	0701		BONN	74 07 15 - 74 11 03	6	90	2170	
AB	160/3	0701		BONN	74 01 26 - 74 04 30	2	80	1924	
AB	190/7	0701		BONN	74 08 15 - 74 10 30	7	80	1916	
AB	190/7	0701		BONN	86 11 21 - 87 06 30	3	222	624	
AB	191/1	0701		BONN	73 07 30 - 73 10 24	1	81	1926	
AB	202/11	0701		BONN	75 02 08 - 75 04 27	0	79	1894	
A*	206	0701		BONN	70 11 27 - 71 03 12	0	108	2592	1.00
A*	206	0701		BONN	72 03 09 - 72 10 20		223		
A*	210	0701		BONN	71 12 10 - 72 01 19	0	42	1008	1.00
L	298	0701		BONN	75 10 13 - 76 03 19	1	155		
A#	233	0702		* EFFELSBERG	77 10 28 - 80 01 11	32	807	15552	0.80
A	138	0705	H	KARLSRUHE	62 - 65				
LZ	156	0705		* KARLSRUHE	87 12 12 - 88 01 13	0	34	816	1.00
LZ	156	0705		* KARLSRUHE	91 07 03 - 91 10 01	0	92	2208	1.00
LZ	249	0705		* KARLSRUHE	87 12 12 - 88 01 13	0	34	816	1.00

Directory of Gravimeters in use for Earth Tide Measurements

Instr.			Station			Epoch	g	d	r	e
LZ	249	0705		*	KARLSRUHE	91 07 02 - 91 10 03	0	94	2256	1.00
LZ	299	0705			KARLSRUHE	91 10 15 - 91 11 19	1	32		
LZ	299	0705			KARLSRUHE	92 11 26 - 93 03 01	0	95	2280	1.00
ET	16	0706			FRANKFURT	75 12 18 - 76 02 08	0	52	1258	
L	98	0706		*	FRANKFURT	67 11 25 - 75 01 08	38	2603	54240	0.87
NAB	140	0706			FRANKFURT	62 03 25 - 62 07 31		130		
NAB	140	0706		*	FRANKFURT	63 03 09 - 70 05 24	14	2635	28704	0.45
ET	16	0707			HEIDELBERG	73 12 19 - 74 03 01				
NAB	140	0708	H		WINGST	58 01 23 - 58 04 01	2	66		
A	130	0709	X	*	HANNOVER	64 12 25 - 65 04 08				
A	130	0709	X	*	HANNOVER	71 01 24 - 73 07 14	22	905	7152	0.33
AB	130/5	0709	X	*	HANNOVER	74 09 22 - 76 08 11	8	691	6432	0.39
ET	18	0709	X	*	HANNOVER	76 06 24 - 78 01 10	4	567	11376	0.84
G	74	0709	X	*	HANNOVER	73 04 06 - 73 09 09	3	159	3600	0.95
LD	8	0709	X	*	HANNOVER	73 05 19 - 73 07 24	8	68	1248	0.77
LDZ	8	0709		*	HANNOVER	85 09 23 - 85 10 13	0	22	528	1.00
LDZ	14	0709		*	HANNOVER	85 05 29 - 88 07 12	0	45	1080	1.00
LZ	79	0709		*	HANNOVER	92 07 02 - 92 10 25	0	116	2784	1.00
LZ	87	0709		*	HANNOVER	92 04 16 - 92 10 18	4	158		
L	260	0709	X	*	HANNOVER	72 12 23 - 74 02 20	16	426	5040	0.49
L	298	0709	X	*	HANNOVER	73 09 20 - 80 05 01	4	2418	10464	0.18
LZ	299	0709	X	*	HANNOVER	73 05 30 - 73 07 29	0	64	1488	1.00
LZ	299	0709		*	HANNOVER	92 06 30 - 92 10 12	0	95	2280	1.00
LZ	995	0709		*	HANNOVER/D	92 04 16 - 92 07 27	1	97		
A	130	0710		*	BAD GRUND	72 03 23 - 72 06 14	2	85	1536	0.76
A	79	0711	D		BERCHTESGADEN	83 07 21 - 84 05 19	1	305	5136	0.70
AB	79/3	0711		*	BERCHTESGADEN	77 08 23 - 83 06 07	64	2116	25680	0.51
ET	16	0711			BERCHTESGADEN	74 07 07 - 74 08 17	2	28	336	
LZ	380	0711			BERCHTESGADEN	78 04 27 - 78 06 05	0	40	960	1.00
NAB	140	0711	H		BERCHTESGADEN	58 07 22 - 58 11 06	1	58		
ET	18	0712		*	CLAUSTHAL	76 02 10 - 76 06 19	0	132	3168	1.00
A	146	0713			HELGOLAND	63 08 04 - 65 09 08	5	230	5520	
A*	210	0713			HELGOLAND	72 07 17 - 73 10 24		100		
A*	204	0714			BUESUM	72 07 11 - 73 07 10		364		
A*	204	0715		*	KIEL	70 01 20 - 70 04 14	0	86	2064	1.00
A*	204	0715			KIEL	72 02 18 - 72 07 09		142		
A*	204	0715			KIEL	73 10 08 -				
A*	210	0715		*	KIEL	70 02 09 - 70 04 14	0	66	1584	1.00
A*	210	0715			KIEL	72 02 18 - 72 09 25		142		
A*	219	0715			KIEL	72 02 18 - 72 09 25		220		
ET	16	0715			KIEL	74 11 14 - 74 12 09		25		
L	98	0715			KIEL	74 11 10 - 74 12 10				
ET*	19	0716			SCHILTACH	80 09 26 - 82 08 15		689		
ET*	19	0716		*	SCHILTACH	88 12 08 - 89 04 10	1	125	2880	0.96
ET*	19	0716			SCHILTACH	90 07 07 - 90 10 29		114		
ET*	19	0716		*	SCHILTACH	91 02 15 - 91 11 27	0	286	6864	1.00
LDZ	14	0716			SCHILTACH	90 07 17 - 91 01 03	3	166		
LZ	156	0716		*	SCHILTACH	88 12 08 - 89 04 09	2	124	1824	0.62
LZ	249	0716		*	SCHILTACH	88 12 09 - 89 04 10	1	124	2880	0.97

Directory of Gravimeters in use for Earth Tide Measurements

Instr.			Station	Epoch	g	d	r	e
LZ	709	0716	SCHILTACH	90 07 17 - 91 01 03	3	166		
L	250	0717 D	FURSTENFELDBRUCK	71 03 09 - 71 05 21	1	68	1632	
ET	16	0718	OBRIGHEIM	73 12 20 - 74 02 28	1	70	1272	
ET	16	0719	STUTTGART	74 04 20 - 74 05 20	2	30	538	
GWRT	6	0731	WETTZEL	90				
ET	16	0732	BRAUNSCHWEIG	74 10 11 - 74 11 10	1	28	666	
ET	16	0733	DARMSTADT	72 12 06 - 73 06 12	0	188	4510	
ET	16	0733	DARMSTADT	73 07 11 - 73 12 09	0	151	3630	
L	195	0733	DARMSTADT			24		
ET*	15	0734 *	BAD HOMBURG	84 01 05 - 84 07 07	0	186	4460	1.00
GWRT	1	0734 *	BAD HOMBURG	81 08 01 - 84 05 01	0	1004	24096	1.00
GWRT	101	0734	BAD HOMBURG	86 03 22 - 88 12 27			24272	
GWRT	103	0734	BAD HOMBURG					
ET	16	0735	MUNSTER	74 12 13 - 75 01 07	0	25	607	
L	98	0735	MUNSTER	74 12 11 - 75 01 10				
ET	16	0736	WUERZBURG	75 09 28 - 75 11 03	0		877	
ET	16	0737	MUENCHEN	74 05 24 - 74 06 24	1	31	668	
L	195	0737	MUENCHEN			84		
ET	16	0739	WOLFSTEIN	75 01 18 - 75 03 31	1	73	1556	
GWRT	8	0742	ASSE SALT MINE	89 04 27 - 91 05 31		672		
A*	206	0750	BERLIN	79 01 02 - 79 04 11				
A*	210	0750	BERLIN	84 01 16 - 84 05 03				
ET	16	0750 D	BERLIN	74 08 22 - 74 10 06	3	33	790	0.72
ET	18	0750	BERLIN	78 09 07 - 80 02 21	13	399	9579	
L	318	0750 D *	BERLIN	78 03 29 - 79 05 05	2	404	8880	0.92
A	127	0761 H	KIESELBACH	63 10 16 - 63 11 23	0	40		
AD	162	0762	TIEFENORT	85 - 91 01 01				
A	127	0763 H	BAD SALZUNGEN	63 08 09 - 63 09 28	0	52		
A	127	0765 H	POTSDAM	63 01 19 - 63 02 18	0	32		
A	137	0765 H	POTSDAM	70 05 - 75		1298	1032	
A	162	0765 H	POTSDAM	63 01 19 - 63 02 18	0	32		
AD	162	0765	POTSDAM	84 01 - 84 12				
A	188	0765 H	POTSDAM	73 07 07 - 78 06 04			1264	
AD	188	0765	POTSDAM	86 03 26 - 86 07 03	0	99		
AB	190/7	0765 X *	POTSDAM	79 01 13 - 79 12 09	0	332	7968	1.00
A*	222	0765 *	POTSDAM	74 03 22 - 90 06 06	15	5922	129738	0.91
A*	222	0765 *	POTSDAM	82 02 26 - 93 03 30	2	4052	93360	0.96
ET*	16	0765	POTSDAM	90 08 07 - 91 04 10	4	244		
GWRT	18	0765 *	POTSDAM	92 06 30 - 93 04 01	0	274	6576	1.00
LZ	156	0765 *	POTSDAM	91 12 05 - 92 03 30	0	114	2736	1.00
LZ	249	0765 *	POTSDAM	91 12 05 - 92 03 30	0	114	2736	1.00
LZ	318	0765 *	POTSDAM	91 02 09 - 93 04 07	7	789	17760	0.94
LZ	995	0765 *	POTSDAM	91 12 05 - 92 03 30	0	108	2592	1.00
LZ	995	0765	POTSDAM	93 01 -				
A	127	0766 H	FREIBERG	63 03 10 - 63 07 31	1	62		
A	127	0769 H	BERGGIESHUEBEL	64 02 29 - 64 04 27	0	60		
L	298	0800 *	LAUGASKOLI	75 07 05 - 75 08 20		47		
G	826	0801 *	BURKFELL/HEKLA	90 08 12 - 91 01 06	3	149	2640	0.74
G	730	0821 *	FAEROE	73 06 18 - 73 12 16	2	183	4272	0.95

Directory of Gravimeters in use for Earth Tide Measurements

Instr.				Station	Epoch	g	d	r	e
G	730	0822	*	AARHUS	74 01 17 - 74 05 20	3	125	2832	0.94
A*	204	0823		BORNHOLM	73 07 26 - 73 09 02		38		
A*	210	0824		SOEGARD	86 05 05 - 86 07 07				
A*	206	0825		VARDE	85 05 02 - 85 05 11				
A*	210	0826		MONSTED	84 05 31 - 84 11 19				
AB	138/6	0827	D	ALBORG	84 08 29 - 85 01 27				
A*	210	0827		ALBORG	85 02 23 - 86 06 14		381		
A*	206	0828		ROLFSTED	86 04 04 - 86 07 02				
A*	206	0829		KOBENHAVN	88 05 03 - 88 08 20		58		
A*	210	0829		KOBENHAVN	87 08 05 - 87 11 26				
ET*	18	0829		KOBENHAVN	86 11 09 - 87 02 26		110		
A*	206	0830		MOGELTONDER	87 05 10 - 87 09 12				
AB	85/2	0842	*	OSLO	74 02 20 - 74 04 07	0	48	1152	1.00
AB	85/2	0843	*	BERGEN	74 05 28 - 74 08 15	4	81	1776	0.91
AB	85/2	0844		TRONDHEIM	74 09 09 - 75 04 07	-	159	-	-
G	761	0844	*	TRONDHEIM	75 05 09 - 75 08 30	3	115	1536	0.56
A*	206	0845		HEMNESBERGET	83 03 25 - 83 10 15	0	204	4896	1.00
AB	85/2	0846	*	BODOE	75 04 14 - 75 10 03	6	175	2880	0.69
AB	85/2	0847	*	TROMSOE	75 10 14 - 76 01 16	6	96	1968	0.85
A*	206	0848	*	NESNA	80 04 15 - 80 12 13	11	244	5232	0.89
ET	18	0849	*	UMBUKTA	80 04 08 - 81 01 06	6	275	4896	0.74
A*	224	0860		GÖTEBORG	84 06 20 - 85 03 04	4	257	5617	0.91
A	168	0861	H	STOCKHOLM	63 04 10 - 67 01 13	34	1154		
A	168	0861	H	STOCKHOLM	67 12 22 - 68 04 24	6	192		
A	168	0861	*	STOCKHOLM	74 05 10 - 74 07 03	1	57	1248	0.92
AB	202/11	0862	X	DANNEMORA	75 08 13 - 75 10 11	0	60	1438	-
AB	202/11	0862	*	DANNEMORA	76 01 23 - 82 11 29	34	2505	37968	0.63
A*	224	0864	*	UPPSALA	81 04 03 - 82 09 13	12	530	10944	0.86
G	761	0866	D *	KRAMFORS	75 09 11 - 76 01 17	2	131	3024	0.97
G	761	0867	*	GAVLE	76 01 23 - 76 06 02	3	134	3024	0.94
G	761	0868	*	VIVATTNET	76 06 19 - 76 10 15	7	121	2208	0.76
G	761	0869	*	BOXHOLM	76 11 12 - 77 02 21	1	103	2208	0.89
ET	18	0870		TARNABY	82 02 20 - 82 06 02	0	120	2863	1.00
AB	138/6	0871	D	STORUMAN	83 04 03 - 83 08 29	9		1262	
ET	18	0881	*	LOHJA	85 08 18 - 86 04 14	11	241	4752	0.82
A	187	0882	D	HELSINKI 1	64 09 26 - 66 05 21	20	356		
A	187	0882	*	HELSINKI 1	66 05 28 - 67 05 21	2	354		
AB	187/20	0882	*	HELSINKI 1	84 01 29 - 84 06 07	2	131	2880	0.92
A	187	0883		HELSINKI 2	67 06 10 - 73 04 03		596		
G	761	0883		HELSINKI 2	71 11 01 - 72 03 05	5	127	2784	0.91
G	761	0883		HELSINKI 2	73 09 25 - 73 12 27	7	95	1776	0.78
G	761	0883		HELSINKI 2	75 04 01 - 75 04 29	0	30	720	1.00
G	761	0883	*	HELSINKI 2	79 03 03 - 80 03 17	8	383	8400	0.92
L	258	0883		HELSINKI 2	72 05 15 - 72 09 08				
G	761	0885		OULU	72 03 27 - 72 06 24	2	91	1680	0.77
G	761	0885	*	OULU	80 04 16 - 80 10 17	6	186	4176	0.94
G	761	0886	*	KEVO	72 08 03 - 72 12 18	1	140	3312	0.99
LZ	402	0886	*	KEVO	84 04 02 - 84 09 11	6	165	3504	0.88
L	665	0886	*	KEVO	84 03 31 - 84 09 14	2	170	3984	0.98

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Instr.				Station	Epoch	g	d	r	e
G	761	0887	D	* SODANKYLA	72 12 22 - 73 05 03	0	134	3216	1.00
G	761	0887		* SODANKYLA	80 10 27 - 81 04 17	9	175	3504	0.84
G	761	0888		* VAASA	74 02 02 - 74 05 21	0	110	2640	1.00
G	761	0888		* VAASA	77 09 17 - 77 12 17	1	94	2016	0.90
G	761	0889		* JOENSUU	74 07 03 - 74 10 29	0	120	2880	1.00
A*	210	0890		* VAAJAKOSKI	82 02 08 - 82 07 23	7	168	3504	0.87
G	761	0890		* VAAJAKOSKI	74 11 24 - 75 03 02	3	119	2352	0.83
AB	187/20	0891		* VIROJOKI	83 02 24 - 83 04 29	3	66	672	0.42
ET*	18	0892		* METSÄHOVI	87 05 24 - 91 10 25	27	1617	30672	0.79
A	110	0905		* VARSOVIE	71 06 16 - 72 02 23	11	254	5184	0.85
AB	110/17	0905		* VARSOVIE	80 01 15 - 82 04 18	22	826	18144	0.92
AD	112	0905		* VARSOVIE	80 01 08 - 83 05 10	29	1221	26064	0.89
AD	188	0905		* VARSOVIE	86 08 02 - 89 04 60	28	1004	22416	0.93
A	133	0923	H	* PRIBRAM	68 09 02 - 68 12 05	0	96	2304	1.00
A	131	0928		CESKE BUDEJOVICE					
A	131	0928		* CESKE BUDEJOVICE	72 03 11 - 73 03 05	25	361	6384	0.74
A	133	0928		* CESKE BUDEJOVICE	72 07 23 - 73 09 16	21	422	6576	0.65
A	131	0930		* PECNY	70 09 03 - 75 07 05	52	1768	16704	0.39
A	131	0930		* PECNY	76 07 09 - 77 08 18	16	407	7200	0.74
A	131	0930		* PECNY	77 12 07 - 80 07 05	62	943	9024	0.40
AB	190/7	0930		* PECNY	75 02 16 - 75 05 25	2	99	2064	0.87
AB	201/26	0930		PECNY	83 04 10 - 86 01 06	54	1004	18384	0.76
A*	220	0930		PECNY	75 01 31 - 75 05 29	2	118	2772	-
A*	222	0930		PECNY	75 02 04 - 75 05 16	5	103	1728	-
A*	228	0930		* PECNY	76 04 23 - 92 01 01	240	5733	84912	0.62
AB	190/7	0950		* BUDAPEST	82 03 11 - 83 12 29	30	660	13776	0.87
AB	190/7	0950		BUDAPEST	84 11 02 - 86 01 01				
AB	190/7	0950		BUDAPEST	88 04 05 - 88 09 05				
A*	228	0950		* BUDAPEST	84 11 02 - 85 12 04	12	399	8160	0.85
LDZ	9	0950		* BUDAPEST	87 11 12 - 88 07 03	8	236	5232	0.92
A	190	0952	H	TIHANY	62 - 66				
A	190	0952	H	TIHANY	66 06 06 - 72 10 07	32	1437		
AB	190/7	0952		TIHANY	74 12 11 - 75 01 19	0	40		
AB	190/7	0952		* TIHANY	77 06 18 - 78 01 22	2	220	4848	0.92
A*	220	0952		* TIHANY	73 09 26 - 74 06 23	3	272	6144	0.94
A*	224	0952		TIHANY	74 02 04 - 74 06 23		140		
ET	16	0952		TIHANY	83 -				
LD	9	0952		* TIHANY	79 05 06 - 79 07 14	2	71	1584	0.93
A	190	0955		* PECS	78 02 16 - 78 06 04	7	110	1344	0.51
AB	190/7	0956		PENC	-			1920	
AB	171/4	1001		CALDARUSANI	75 02 10 - 75 06 29	1	127	3284	
A*	220	1010		* SOFIA	78 01 22 - 79 02 11	16	385	7728	0.84
A*	221	1010		* SOFIA	78 02 19 - 79 02 10	14	358	7440	0.87
A*	228	1010		* SOFIA	81 12 06 - 82 12 05	6	366	8208	0.94
G	151	1035		* ZAGREB	84 02 26 - 84 11 02	18	252	4656	0.77
GWRT	17	1051		THESSALONIKI	93 01 -				
LZ	265	1051		THESSALONIKI	90 10 30 - 91 06 09	4	164		
A	147	1102	H	TALLINN	65 11 - 77 07 10	4	609	13536	
AR	147/2	1102		TALLINN	85 06 29 - 86 11 25	1	515	11520	

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Instr.					Station	Epoch	g	d	r	e
AB	190/7	1105		*	POULKOVO	76 05 13 - 76 10 20	0	158	3792	1.00
A	201	1105			POULKOVO	76 05 13 - 76 10 06		128	3204	1.00
A*	220	1105		*	POULKOVO	76 05 25 - 77 01 15	1	238	5664	0.99
A	124	1117	H		OBNINSK	68 06 28 - 68 11 26		152		
A	135	1117	H		OBNINSK	68 12 27 - 69 05 07		132		
A	135	1117	H		OBNINSK	70 05 16 - 72 01 04		303		
A	135	1117	H		OBNINSK	74 02 10 - 75 08 11		423		
A	190	1117	H		OBNINSK	73 01 22 - 73 12 20		333	7992	1.00
AB	190/7	1117	H	*	OBNINSK	75 08 22 - 76 06 13	5	235	5424	0.97
A*	220	1117			OBNINSK	73 04 27 - 73 12 25		121		
A*	220	1117	D		OBNINSK	74 08 28 - 76 04 19		202		
A*	220	1117		*	OBNINSK	75 11 30 - 76 04 17	1	142	3360	0.99
A*	220	1117		*	OBNINSK	77 02 12 - 77 11 29	12	289	6384	0.92
A*	220	1117			OBNINSK	79 05 11 - 81 01 19		620		
A*	221	1117	D	*	OBNINSK	75 08 30 - 76 04 18	3	232	5280	0.95
A*	221	1117		*	OBNINSK	77 05 19 - 78 01 30	12	258	5616	0.91
A*	224	1117	D		OBNINSK	76 12 15 - 78 12 05		690	5436	
A	124	1119			KR.PAKHRA	68 12 01 - 70 08		77	5000	
A	180	1119			KR.PAKHRA	67 10 -		862	2520	
A	180	1119			KR.PAKHRA	70 05 - 72 05			17592	
A	124	1142	H		KIEV	60 12 23 - 61 07		175	4200	
A	126	1142	H		KIEV	60 - 61				
A	134	1142	H		KIEV	60 - 61				
A	135	1142	H		KIEV	60 08 04 - 61 02		180	4320	
A	159	1150			SIMFEROPOL	65 01 17 - 66 05 22	15	491	11088	0.94
A	159	1151			YALTA	66 06 29 - 68 06 16	12	781	15504	0.90
A	159	1152	H		POLTAVA	61 09 06 - 64 01 30	6	876	17136	0.82
A	159	1152	H		POLTAVA	73 11 27 - 75 09 29		640	15360	0.97
A	159	1152	H		POLTAVA	75 11 16 - 76 12 26		407	9768	0.98
A	159	1152			POLTAVA	87 11 28 - 91 11 30		1799	43176	0.98
A	185	1152	H		POLTAVA	73 11 25 - 74 04 13	0	138	3312	1.00
A	185	1152	H		POLTAVA	76 01 08 - 76 11 26		324	7776	0.99
A	185	1152			POLTAVA	80 04 21 - 81 09 30	0	528	12672	1.00
A	185	1152			POLTAVA	87 11 28 - 89 04 26		516	12384	0.99
A	185	1159	D		SIMEIZ	81 10 20 - 84 12 25		1162	20160	0.72
A	159	1165			BAKHTCHISSARAI 1	68 08 02 - 68 11 23		114	1848	0.68
A	159	1165			BAKHTCHISSARAI 2	70 02 07 - 71 01 26		543	8808	0.68
A	185	1165			BAKHTCHISSARAI 1	68 07 26 - 69 02 14		202	2904	0.60
A	185	1165			BAKHTCHISSARAI 2	70 05 20 - 71 09 07		566	8592	0.63
AB	144	1190			TBILISSI/DUSHETI					
A	166	1190			TBILISSI/DUSHETI	60 00 -				
A	126	1270			TASHKENT	59 11 - 60 06		179	4296	
A	134	1270			TASHKENT	59 11 - 60 06		179	4296	
A	126	1280	H		FRUNZE/BISHKEK	60 11 - 61 07		227	4680	
A	134	1280	H		FRUNZE/BISHKEK	60 10 - 61 07		195	5448	
AB	201/26	1280		*	FRUNZE/BISHKEK	89 01 02 - 90 04 21	16	477	10320	0.90
A	159	1289			NOVOSIBIRSK	66 12 - 70 12				
A	180	1289			NOVOSIBIRSK	66 12 - 70 12			17304	
A	186	1289			NOVOSIBIRSK	66 12 - 70 12		989		

Directory of Gravimeters in use for Earth Tide Measurements

Instr.				Station	Epoch	g	d	r	e
A	186	1289	*	NOVOSIBIRSK	85 05 18 - 90 08 18	60	1920	30816	0.67
A	126	1293		TALGAR	61 11 11 - 67 06		1857	44520	
A	134	1293		TALGAR	61 11 11 - 71 08		1445	34680	
A	167	1293		TALGAR	67 08 07 - 77 07		3015	70896	
A	167	1293		TALGAR	72 12 27 - 78 09 03				
A	167	1293		TALGAR	78 09 28 - 79 09 18				
A	167	1293		TALGAR	81 04 01 - 81 03 30				
A	186	1293		TALGAR	74 01 - 74 12		356	8544	
A	180	1300		IRKUTSK	79 09 - 88 02				
A	186	1300		IRKUTSK	79 09 - 88 02			22372	
G	783	2000	*	ISTANBUL	77 11 20 - 78 05 31	12	194	3696	0.79
G	783	2001	*	ANKARA	78 06 08 - 79 05 13	15	350	5040	0.60
A	25	2201		TEHERAN	81 02 19 - 81 11 15	27	271	3120	0.48
A	119	2201		TEHERAN	64 08 30 - 70 11 12	17	2263	39600	0.73
A	119	2201		TEHERAN	74 07 03 - 76 09 22	57	811	8784	0.45
L	402	2201	*	TEHERAN	77 12 21 - 78 06 25	8	187	3936	0.88
L	402	2202	*	TABRIZ	78 07 01 - 79 06 03	24	338	6864	0.85
L	8	2350	*	QUETTA	77 11 28 - 78 06 11	12	201	1680	0.35
L	8	2351	D *	LAHORE	78 06 15 - 79 02 13	11	243	1392	0.24
G	765	2352	*	PESHAWAR	78 06 22 - 79 02 12	21	236	4176	0.74
G	804	2401	*	NEW DELHI	74 11 11 - 75 03 30	7	141	1584	0.47
L	2	2401		NEW DELHI	58 01 14 - 58 02 13	0	32	768	1.00
G	804	2402	D *	HYDERABAD	73 12 11 - 74 08 29	20	263	3168	0.50
L	84	2403	H *	DEHRA DUN	73 04 06 - 73 07 03	0	90	2160	1.00
G	84	2450	*	KATHMANDU	74 09 30 - 75 03 13	15	165	1776	0.45
G	765	2450	*	KATHMANDU	82 12 08 - 83 06 10		0	0	0.00
L	402	2450	*	KATHMANDU	82 12 08 - 83 03 20		0	0	0.00
L	402	2450	*	KATHMANDU	83 03 27 - 83 11 18	11	238	4032	0.71
G	765	2460	*	COLOMBO	77 11 20 - 78 05 05	7	168	3744	0.93
G	84	2501	*	BANGKOK	73 11 17 - 74 03 15	8	120	2208	0.77
A*	226	2502	*	CHIANG MAI	74 04 12 - 74 09 01	16	144	1920	0.56
G	84	2502	*	CHIANG MAI	74 04 09 - 74 09 08	14	154	2928	0.79
L	8	2502	*	CHIANG MAI	82 05 03 - 82 12 06	8	219	4320	0.82
G	765	2550	*	KUALA LUMPUR	76 11 11 - 77 04 25	5	167	3744	0.93
G	765	2551	*	PENANG	76 04 09 - 76 10 27	13	203	3600	0.74
G	765	2555	*	KOTA KINABALU	77 04 30 - 77 11 11	19	197	3552	0.75
G	783	2600	*	GUANGZHOU	80 03 16 - 80 09 18	4	188	4272	0.95
L	3	2601	*	HONG KONG	74 04 20 - 74 09 09	9	143	2640	0.77
A*	231	2603		BEIJING			378		
G	765	2603	*	BEIJING	79 10 01 - 80 03 15	4	168	3792	0.94
G	832	2603		BEIJING	81 03 -				
A*	211	2604		KUNMING	75 04 12 - 79 02 28				
A*	211	2604		KUNMING	78 11 25 - 81 01 01		606		
A*	211	2604		KUNMING	81 01 01 - 92 12 31				
A*	231	2604		KUNMING	80 02 03 - 80 08 16		196		
L	402	2604	*	KUNMING	80 03 18 - 81 05 27	8	436	9024	0.86
A	150	2605		LANZHOU	??				
A*	218	2605	*	LANZHOU	80 03 30 - 80 09 28	5	184	4176	0.95
ET*	16	2605	*	LANZHOU	92 08 28 - 93 10 03	16	403	8688	0.90

Directory of Gravimeters in use for Earth Tide Measurements

Instr.		Station		Epoch		g	d	r	e
G	765	2605	*	LANZHOU	80 03 24 - 81 05 17	2	421	9648	0.95
A*	216	2606	*	URUMQI	80 03 28 - 80 09 26	4	184	4224	0.96
A*	216	2606		URUMQI	81 01 01 - 92 12 31				
A*	218	2606		URUMQI	82 09 02 - 92 12 31				
G	84	2606	*	URUMQI	80 03 25 - 80 09 25	6	185	4128	0.93
A	149	2607		WUHAN	72 01 08 -		174	4176	
A*	227	2607		WUHAN	85 06 01 - 86 06 30				
ET	15	2607	*	WUHAN	87 05 05 - 88 04 06	0	314	7536	1.00
ET*	16	2607		WUHAN	85 - 89 01				
ET	20	2607		WUHAN	86 12 22 - 87 08 29	0	190	4560	1.00
ET	21	2607		WUHAN	85 05 30 - 88 04 05	19	1042	23616	0.94
ET*	21	2607		WUHAN	92 08 01 - 92 10 20				
ET	22	2607		WUHAN	86 09 11 - 87 06 30				
G	84	2607	*	WUHAN	79 10 08 - 80 02 15	3	132	3024	0.95
G	765	2607	*	WUHAN	81 05 29 - 82 05 13	5	351	8160	0.97
G	783	2607	*	WUHAN	79 10 09 - 80 03 07	0	152	3648	1.00
G	783	2607	*	WUHAN	80 10 02 - 81 05 07	8	219	4656	0.89
GWRT	4	2607	*	WUHAN	85 11 24 - 88 08 24	4	1006	23808	0.99
GWRT	4	2607	*	WUHAN	88 11 17 - 91 11 19	28	1099	23616	0.89
L	402	2607	*	WUHAN	79 10 11 - 80 03 06	3	148	3408	0.96
LZ	584	2607		WUHAN			96	2304	
G	84	2610	*	SHENYANG	80 10 14 - 81 11 19	11	403	5952	0.62
A*	231	2612		SHANGHAI	80 09 21 - 81 04 16		180		
ET*	16	2612		SHANGHAI ZO SE	89 01 - 89 12				
G	783	2612	*	SHANGHAI ZO SE	81 05 30 - 82 04 24	9	331	7248	0.91
A*	227	2613		SHANGHAI TUNEL	78 04 - 78 08		142		
A*	227	2613		SHANGHAI	81 01 03 - 83 08 30				
G	84	2614	*	TSING TAO	81 11 26 - 82 10 21	12	326	7008	0.90
G	703	2616		DA TONG	81 02 23 - 84 08 13	31	902	20774	0.96
G	703	2617		BAIJIATUAN	84 10 18 - 85 03 02	1	136	3170	0.97
G	710	2617		BAIJIATUAN	84 11 10 - 85 03 02	3	113	2618	0.97
G	718	2617		BAIJIATUAN	84 10 18 - 85 03 02	4	136	3170	0.97
G	721	2617		BAIJIATUAN	84 10 21 - 85 02 11	4	114	2643	0.97
G	728	2617		BAIJIATUAN	84 10 20 - 85 03 02	3	134	3119	0.97
G	804	2617		BAIJIATUAN	81 05 02 - 90 08 08	31	3386	80414	0.99
G	804	2617		BAIJIATUAN	90 08 09 - 90 09 11				
G	804	2617		BAIJIATUAN	90 09 12 - 93 05 24	3	986	23374	0.99
G	832	2617		BAIJIATUAN	84 10 18 - 85 02 18	2	123	2877	0.98
G	834	2617		BAIJIATUAN	84 10 21 - 85 03 02	2	133	3098	0.97
A*	232	2618		BAODI	83 01 01 - 92 12 31				
A*	232	2618	*	BAODI	93 01 02 - 93 06 28	1	179	4224	0.98
G	721	2618		BAODI	81 03 14 - 84 05 14	3	793	18870	0.99
G	721	2618		BAODI	85 02 15 - 93 01 13	23	2890	66166	0.95
ET	21	2619		WAN XIAN	84 08 07 - 85 01 20	5	167	3792	0.95
G	832	2620		WENAN	81 03 31 - 83 04 12	25	743	17390	0.98
ET	20	2621		CHENGDE	84 12 07 - 85 08 02	4	239	5424	0.94
G	728	2621		CHENGDE	81 04 23 - 84 08 07	30	1203	27251	0.94
G	728	2621		CHENGDE	86 08 25 - 93 01 15	103	2336	48290	0.86
G	710	2622		BEIDAIHE	81 04 20 - 84 08 18	56	1217	26717	0.91

Directory of Gravimeters in use for Earth Tide Measurements

Instr.		Station			Epoch	g	d	r	e
G	710	2622			BEIDAIHE	86 11 26 - 91 02 12	79	1572	32189	0.85
G	703	2624			ZHANGJIAKOU	86 11 21 - 91 09 10	52	1755	38891	0.92
G	718	2624			ZHANGJIAKOU	81 05 23 - 84 08 07	5	1173	27970	0.99
A*	215	2626		*	YINCHUAN	93 01 04 - 93 06 12	2	161	3744	0.97
A*	207	2633			QUANZHOU	82 04 15 - 82 07 27	6	104	2256	0.90
LZ	584	2633			QUANZHOU	82 04 07 - 82 07 15	2	100	2352	0.98
LZ	589	2633			QUANZHOU	82 04 05 - 82 08 24	3	142	3264	0.96
A*	205	2636			ZHENZHOU	81 04 02 - 92 12 31				
ET	21	2636			ZHENZHOU	84 01 18 - 84 07 21	3	185	4224	0.95
A*	231	2637			PI COUNTRY/SICHUAN			94		
ET	20	2638			HEIFEI	84 02 17 - 84 05 14	3	87	1324	0.87
G	834	2639			WAN XIAN	81 03 22 - 84 07 23	24	1220	28846	0.99
G	834	2639			WAN XIAN	86 01 11 - 91 04 26	46	1933	44736	0.96
ET	20	2640			HINADO	83 01 09 - 83 03 22	6	73	1344	0.77
LZ	584	2640			HINADO	83 01 09 - 83 06 10	8	152	3312	0.91
LZ	589	2640			HINADO	83 01 09 - 83 05 08	8	118	2544	0.90
A*	227	2641		*	DALI	93 01 02 - 93 06 29	7	180	3696	0.86
A*	215	2642			YINCHAN	82 03 22 - 92 12 31				
A*	213	2643			PIXIAN	81 01 01 - 92 12 31				
A*	227	2644			XIAGUAN	86 10 01 - 92 12 31				
A*	229	2645			DUKOU	81 01 01 - 92 12 31				
A*	230	2646			MIDU	84 01 01 - 92 12 31				
ET	22	2647			LIJIAN	90 08 01 - 92 07 30				
ET*	21	2648			DUNHUANG	93 -				
G	832	2649			TAINJIN	86 05 08 - 88 07 26	8	810	19302	0.99
G	832	2649			TAINJIN	88 07 26 - 89 04 12				
G	832	2649			TAINJIN	89 04 12 - 93 05 04	21	1484	31089	0.91
A*	231	2650			LHASA			134		
ET	20	2650			LHASA	83 05 17 - 83 10 01	4	142	2928	0.86
ET	21	2650			LHASA	83 05 17 - 83 10 01	6	142	2832	0.83
L	2	2701	H	*	SAIGON	57 11 24 - 57 12 30	0	38	912	1.00
G	84	2750		*	SEOUL	82 10 29 - 83 05 28	10	213	2544	0.50
A	111	2823	H		KYOTO	59 08 01 - 60 08 17	0	383	9192	1.00
A*	217	2823	H		KYOTO	72 06 - 75 05		1095	7520	0.67
A*	217	2823		*	KYOTO	82 11 02 - 83 05 29	3	210	4752	0.94
G	783	2823		*	KYOTO	82 11 06 - 83 05 21	7	198	4272	0.90
GWRT	9	2823			KYOTO	88 07 30 - 93 04	1	1350	19930	0.62
GWRT	10	2823			KYOTO	88 07 30 - 91 04	0	1720	41280	1.00
ET	17	2827			IZU-OSHIMA	85 09 20 - 89 03 20	231	1278	22320	0.73
L	34	2832			YATSUGATAKE	81 05 09 - 81 08 26				
L	34	2836			YAHIKO	80 12 09 - 81 05 08				
L	375	2840			ABURATSUBO	77 12 23 - 78 01 13				
L	447	2840			ABURATSUBO	77 12 23 - 78 01 13				
L	29	2842			NOKOGIRIYAMA	77 12 25 - 78 01 02				
ET	17	2845			TSUKUBA	81 04 17 - 81 12 16	11	254	4683	0.80
ET	17	2845			TSUKUBA	82 06 15 - 85 09 09	93	1183	23845	0.84
ET	17	2845			TSUKUBA	89 05 19 - 89 08 26	3	100	2365	0.99
ET	17	2845			TSUKUBA	90 02 15 - 90 07 02	6	138	2545	0.77
A	105	2847	H		MIZUSAWA	68 09 02 - 68 11 15	0	76		

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Instr.			Station		Epoch	g	d	r	e
A	111	2847	H	MIZUSAWA	68				
A	193	2847	H	MIZUSAWA	68 09 01 - 68 11 16	0	78		
A	197	2847	H	MIZUSAWA	67 11 02 - 68 11 15	1	198		
A	197	2847		MIZUSAWA	72 01 02 - 72 12 30	11	365	5712	0.65
G	163	2847	*	MIZUSAWA	74 09 26 - 75 08 24	29	334	5424	0.68
L	29	2847	H	MIZUSAWA	68 08 31 - 68 10 06	0	38		
L	29	2847		MIZUSAWA	76 12 27 - 77 03 12				
L	34	2847	H	MIZUSAWA	68 08 31 - 68 10 06	0	38		
L	304	2847		MIZUSAWA	76 12 27 - 77 03 12				
L	305	2847		MIZUSAWA	73 09 13 - 73 09 28				
L	305	2847	*	MIZUSAWA	74 09 17 - 76 03 30	10	562	7584	0.56
L	305	2847		MIZUSAWA	75 11 11 - 76 03 30		74		
L	305	2847		MIZUSAWA	76 12 27 - 77 03 12		38		
L	308	2847		MIZUSAWA	76 12 27 - 77 03 12				
L	402	2847	*	MIZUSAWA	81 06 10 - 81 11 11	7	156	3456	0.92
L	447	2847		MIZUSAWA	76 12 27 - 77 03 12				
A	197	2848		AKAGANE	69 09 09 - 69 10 11	0	34	816	1.00
L	305	2848		AKAGANE	74 03 09 - 74 04 06	2	26	-	-
GWRT	7	2849		ESASHI	88 04 - 89 03		720		
LZ	457	2849	*	ESASHI	80 01 02 - 80 12 29	9	365	7872	0.90
LZ	457	2849		ESASHI	81 01 02 - 81 12 27	9	365	6616	0.76
L	447	2853		INUYAMA	83 03 15 - 83 09 09				
L	34	2856		FUJIGAWA	80 08 22 - 80 12 12				
LD	58	2870		SHIZUOKA	84 04 05 - 92 06 15		2990	69600	0.97
L	680	2870		SHIZUOKA	84 09 03 - 93 04	1	2850	42120	0.62
L	402	2875	*	KANOYA	82 05 12 - 82 11 04	17	178	2928	0.69
G	783	2877	*	TOKYO	82 05 09 - 82 10 25	10	171	3408	0.83
L	34	2877	*	TOKYO	80 03 30 - 81 11 18	11	600	7488	0.52
LDZ	63	2877		TOKYO	86 05 11 - 86 08 22				
L	447	2877	*	TOKYO	80 03 30 - 81 11 18	11	600	7392	0.51
LZ	447	2877		TOKYO	84 01 22 - 84 03 19				
LDZ	63	2879		FUKUSHIMA	84 10 02 - 85 02 14				
LZ	447	2882		KANAZAWA	85 08 30 - 85 11 23				
L	34	2883		NAGANO	82 05 24 - 82 09 07				
L	34	2884		KIRYU	82 09 08 - 83 02 09				
GWRT	11	2885		KAKIOKA	89 11 - 93 04 30	3	1276	30384	0.99
L	447	2885		KAKIOKA	82 08 28 - 83 02 14				
LZ	447	2886		TAKAYAMA	84 04 25 - 84 11 28				
L	34	2887		MATSUMOTO	83 03 29 - 83 10 03				
L	402	2897	*	MEMAMBETSU	81 11 17 - 82 04 24	8	160	3504	0.91
L	336	3000	D *	CAIRO/HELWAN	74 09 26 - 75 01 24	12	122	1440	0.49
L	3	3001	*	ASSOUAN	78 11 07 - 79 09 12	12	308	2256	0.30
L	3	3010	*	KHARTOUM	79 09 18 - 80 03 04	9	169	3312	0.81
L	336	3014	*	ADDIS ABABA	81 05 06 - 81 10 28	6	174	3792	0.90
L	336	3018	*	ARTA DJIBOUTI	81 10 31 - 82 05 05	2	188	4416	0.98
LD	32	3020	*	MOGADISCIO	80 09 10 - 81 05 07	10	241	3120	0.54
L	336	3030	*	NAIROBI	80 01 18 - 80 10 21	7	279	4944	0.74
L	336	3031	*	VOI	80 12 24 - 81 04 25	5	125	2592	0.86
LD	32	3040	*	DAR ES SALAAM	81 05 19 - 81 11 06	4	120	2496	0.87

Directory of Gravimeters in use for Earth Tide Measurements

Instr.			Station		Epoch	g	d	r	e
LZ	336	3090	* LANZAROTE 1		90 04 14 - 91 02 21	18	315	6480	0.86
LZ	434	3090	* LANZAROTE 1		87 05 15 - 91 06 12	52	1491	28416	0.79
LZ	336	3091	* LANZAROTE 2		91 02 26 - 93 02 06	11	204	4368	0.89
LZ	336	3092	* LANZ.TIMANFAYA		93 02 07 - 93 07 23	6	168	3792	0.94
LZ	8	3102	* IFRANE		90 07 20 - 90 10 19	5	94	1680	0.75
LZ	8	3112	* ALGER	D	88 06 04 - 88 11 24	8	175	3600	0.86
LZ	8	3201	* TAMANRASSET		89 03 12 - 90 03 05	7	361	8304	0.96
A*	212	3210	* BU CRAA		75 03 24 - 75 10 10	19	202	3024	0.62
G	765	3221	* LAMTO		84 01 26 - 84 06 18	4	146	3264	0.93
LZ	336	3300	* NOUAKCHOTT		89 03 06 - 89 07 19	7	137	2880	0.88
LZ	8	3311	* M'BOUR		87 10 10 - 88 05 23	16	227	4560	0.84
LZ	336	3312	* KEDOUGOU		87 10 24 - 88 05 14	10	205	3552	0.72
G	765	3325	* OUAGADOUGOU		84 07 07 - 84 11 24	9	143	2688	0.78
LZ	336	3399	* ARLIT		84 06 16 - 84 10 30	10	138	1920	0.58
LZ	336	3400	* NIAMEY		84 01 26 - 84 06 05	15	133	2208	0.69
?	23	3401	BAMAKO	H	65 01 00 - 65 04 00			2160	
A	124	3401	BAMAKO	H	64 12 23 - 65 03 25			2256	
A	135	3401	BAMAKO	H	65 01 03 - 65 03 27	1	68	1632	
LZ	336	3401	* BAMAKO		88 06 01 - 88 10 27	3	150	3504	0.97
NA	167	3401	BAMAKO	H	58 08 00 - 58 09 00			1080	
G	765	3410	* BANGUI		85 01 25 - 85 06 13	1	140	3264	0.97
LZ	336	3410	* BANGUI		85 02 01 - 85 10 27	6	269	5952	0.92
NA	167	3410	BANGUI	H	65 06 00 - 65 07 00		45	1080	
LZ	336	3415	* BRAZZAVILLE		85 12 06 - 86 06 04	4	182	4128	0.95
L	4	3420	* LWIRO	H	58 03 07 - 58 04 06	0	32	768	1.00
L	2	3421	* BUNIA	H	58 03 03 - 58 04 04	0	34	816	1.00
L	336	3451	* BUTARE		82 05 15 - 82 11 08	10	179	3374	0.79
L	3	3495	* HARARE		82 06 30 - 82 11 15	3	140	3216	0.96
LD	32	3500	* MAPUTO		81 11 15 - 82 05 30	8	198	4320	0.91
LD	32	3505	* NAMPULA		82 06 03 - 82 10 30	8	151	3216	0.89
L	3	3601	* ANTANANARIVO		80 03 10 - 80 09 16	8	184	3792	0.86
NA	167	3601	ANTANANARIVO	H	59 01 00 - 59 02 00		1080		
L	3	3602	* NOSY BE		80 10 03 - 81 05 17	6	228	4416	0.81
L	3	3604	* TOLAGNARO		81 05 26 - 82 05 07	14	348	2688	0.32
A*	206	3620	REUNION		74 05 27 - 75 10 18	19	511	11136	0.91
LD	32	3801	* JOHANNESBURG		82 11 26 - 83 05 18	11	174	3648	0.87
L	3	3807	* STELLENBOSCH		82 11 26 - 83 05 16	2	174	4080	0.98
A*	206	3901	WINDHOEK		76 04			2652	
L	2	4010	* BAGUIO	H	57 09 20 - 57 10 30	0	42	1008	1.00
L	305	4010	* BAGUIO		77 12 21 - 78 02 03	0	46	1104	1.00
L	3	4011	* MANILA		73 11 22 - 74 04 12	11	143	2064	0.60
L	305	4011	MANILA		77 11 03 - 77 12 17	0	46	1104	1.00
L	457	4011	MANILA		77 11 03 - 78 02 03	0	94	2256	1.00
L	336	4100	* BANDUNG		76 04 11 - 76 11 10	11	215	4704	0.91
L	8	4105	* BANJAR BARU		79 11 29 - 80 06 15	6	200	4320	0.90
L	336	4110	* UJUNG PANDANG		76 11 21 - 77 04 12	8	144	3072	0.89
L	336	4111	* MANADO		78 07 25 - 78 12 16	12	145	2688	0.77
L	8	4115	* KUPANG		80 06 22 - 81 04 10	17	294	5616	0.80
L	336	4150	* JAYA PURA		77 04 24 - 78 01 01	4	254	1968	0.32

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Instr.			Station	Epoch	g	d	r	e
L	3	4160	* PORT MORESBY	74 09 22 - 75 03 16	13	176	3504	0.83
G	84	4205	* ARMIDALE	75 07 17 - 76 01 24	9	191	3840	0.84
G	84	4206	* CANBERRA	75 04 04 - 75 07 03	3	91	2064	0.95
L	3	4206	* CANBERRA	75 04 01 - 75 06 27	4	88	1872	0.88
L	3	4206	* CANBERRA	76 06 05 - 76 11 07	12	157	2880	0.76
L	8	4206	* CANBERRA 1/2	75 07 22 - 75 11 02	4	94	2304	1.00
L	336	4206	* CANBERRA	75 03 30 - 75 06 27	1	89	2112	0.99
L	398	4206	* CANBERRA	76 07 29 - 76 10 29	7	94	1728	0.77
L	3	4207	* CHARTERS T.	75 12 14 - 76 05 03	12	142	2736	0.80
L	3	4208	* BROKEN HILL	75 07 09 - 75 11 16	11	132	2064	0.65
G	84	4209	* ALICE SPRINGS	76 02 11 - 79 01 04	25	1060	14736	0.58
L	336	4210	* DARWIN	75 11 12 - 76 04 02	5	133	2688	0.84
L	336	4211	* PERTH/MUNDARING	75 07 11 - 75 11 10	6	122	2352	0.80
L	8	4220	* HOBART	75 11 11 - 76 04 30	10	172	3120	0.76
L	8	4400	* HAMILTON	76 11 21 - 77 04 16	8	148	3168	0.89
L	179	4401	* TAUPO	76 12 01 - 77 03 10	3	101	2016	0.84
L	179	4402	RUAPEHU	77 04 08 - 77 04 29	1	20		
L	179	4405	* WELLINGTON	81 06 06 - 82 01 18	7	228	4320	0.79
L	8	4420	* LAUDER	76 07 15 - 76 11 07	6	118	2400	0.85
L	179	4420	* LAUDER	76 06 20 - 76 11 06	7	141	1344	0.40
L	402	4450	* NOUMEA	76 06 23 - 76 11 03	12	136	2256	0.69
L	402	4460	* SUVA FIJI	76 11 18 - 77 04 19	10	153	2304	0.63
L	8	4475	* APIA	77 04 30 - 77 11 12	13	197	3120	0.66
L	402	4480	* PAPEETE	77 05 10 - 77 10 20	9	163	3408	0.87
L	2	6001	H * WAKE	57 07 29 - 57 09 01	0	36	864	1.00
L	2	6003	H * HONOLULU	56 10 15 - 56 11 20	0	38	912	1.00
G	31	6004	* UWEKAHUNA	78 01 29 - 78 12 17	10	324	6912	0.89
L	179	6004	UWEKAHUNA	78 02 09 - 78 03 06	2	27	576	-
UCSD/SGB		6005	KILAUEA VOLCANO	89 12 -				
G	710	6020	POINT ARENA	67 12 29 -				
L	2	6021	H * GLENDORA	57 05 29 - 57 07 06	0	40	960	1.00
UCSD/SGA		6024	* PINON FLAT	73 08 23 - 75 02 26	0	554	12912	0.97
UCSD /SG		6025	LA JOLLA	72 07 06 - 72 08 29				
UCSD/SGA		6025	LA JOLLA	72 10 03 - 73 01 12			100	
UCSD/SGB		6029	FAIRBANKS/ALASKA					
UCSD	1	6035	FAIRBANKS	91 11 24 -				
UCSD	1	6035	FAIRBANKS	91 11 24 -				
G	730	6050	RENO	68 06 01 -				
G	710	6060	EPHRAIM	68 12 19 -				
G	703	6084	DENVER	68 09 24 -				
G	718	6095	DEVILS LAKE	70 02 13 - 70 08 06	2	174	4080	0.98
L	1	6100	AUSTIN	60 01 20 - 62 07 23	5	915	6624	0.30
G	728	6102	WACO	70 02 01 - 70 04 14	1	72	1632	0.83
G	703	6198	SIOUX FALLS	70 01 06 - 70 06 24	8	169	3384	0.83
G	721	6200	MANHATTAN	68 09 06 -				
G	710	6202	LEONARD	70 01 02 - 70 08 17	4	228	3168	0.58
G	786	6205	H RUSTON	70 10 11 - 71 01 03	0	86	2064	1.00
G	735	6295	* BAY S.LOUIS	77 06 03 - 77 09 17	0	108	2592	1.00
G	826	6302	H JACKSON	70 10 12 - 71 01 02	0	84	2016	1.00

Directory of Gravimeters in use for Earth Tide Measurements

Instr.			Station	Epoch	g	d	r	e
G	735	6308	H MEMPHIS	70 10 09 - 70 12 10	0	64	1536	1.00
G	826	6309	H KNOXVILLE	70 07 20 - 70 09 20	0	64	1536	1.00
G	718	6310	URBANA	68 05 09 -				
G	761	6312	H TUSCALOOSA	70 10 13 - 71 01 03	0	84	2016	1.00
G	728	6320	OXFORD	68 05 10 -				
G	826	6322	H ATLANTA	70 03 25 - 70 04 24	0	42	1008	1.00
G	761	6326	H HUNTINGTON	70 07 05 - 70 09 29	0	88	2112	1.00
G	17	6328	* COLUMBIA	84 07 21 - 85 01 31	0	196	4704	1.00
G	761	6328	H COLUMBIA	70 03 13 - 70 06 01	0	82	1968	1.00
G	735	6330	H BLACKSBURG	67 10 04 - 68 01 08	0	98	2352	1.00
G	735	6330	H BLACKSBURG	69 12 16 - 70 02 14	0	62	1488	1.00
G	735	6330	H BLACKSBURG	71 07 22 - 72 03 12	2	233	-	-
G	761	6330	H BLACKSBURG	71 01 11 - 71 03 10	0	60	1440	1.00
G	786	6330	H BLACKSBURG	70 02 11 - 70 03 07	0	76	1824	1.00
G	786	6330	H BLACKSBURG	70 07 31 - 70 10 03	0	66	1584	1.00
G	826	6330	H BLACKSBURG	70 02 11 - 70 03 07	0	26	624	1.00
G	826	6330	H BLACKSBURG	71 01 24 - 71 10 12	3			
G	826	6330	X * BLACKSBURG	85 01 02 - 85 06 29	0	180	4320	1.00
LZ	612	6330	* BLACKSBURG	91 07 05 - 91 12 16	3	166	3696	0.93
G	804	6331	* FAIRFAX	69 02 06 - 70 02 03	0	364	8736	1.00
G	17	6336	* CHARLOTTESVILLE	85 07 14 - 86 01 15	1	187	3408	0.76
G	17	6337	* MORGANTOWN	82 07 23 - 82 10 31	0	102	2448	1.00
G	786	6338	H DURHAM	70 03 19 - 70 06 01	0	76	1824	1.00
L	8	6339	* PITTSBURG NIKE	65 07 17 - 65 12 04	1	142	3360	0.99
L	8	6340	* PITTSBURG CATH	67 05 05 - 68 01 18	7	261	4896	0.78
GWRT	1	6350	RICHMOND	89 10 -				
GWRT	1	6350	RICHMOND	89 12 -				
UCSD		6350	RICHMOND	89 12				
UCSD	1	6350	RICHMOND	90 04 14 - 91 09 25				
G	721	6399	CARLISLE	68 03 01 -				
G	725	6405	NEW YORK	68 01 03 -				
GWRT	12	6802	OTTAWA/CANTLEY	89 11 07 -				
ET	12	6803	* OTTAWA	67 03 23 - 74 12 30	53	2841	24048	0.87
G	786	6803	* OTTAWA	73 05 02 - 74 12 31	7	610	13584	0.93
ET	12	6804	* HOLLAND MILLS	70 04 30 - 70 06 13	1	46	816	0.74
ET	12	6811	* ALERT	71 05 11 - 71 08 21	0	104	2496	1.00
L	4	6900	H * BERMUDA	57 10 31 - 57 12 16	0	48	1152	1.00
G	783	6911	* MARTINIQUE	89 05 21 - 89 10 29	3	163	3696	0.94
LZ	402	6975	* TRINIDAD	89 05 25 - 89 09 26	4	126	2736	0.91
LZ	402	7002	* MEXICO	90 03 16 - 91 02 21	13	345	2592	0.31
G	783	7105	* GUATEMALA	90 03 08 - 90 08 15	6	162	3504	0.90
LZ	402	7118	* SAN JOSE	89 11 14 - 90 03 02	5	110	2304	0.88
G	783	7119	* GUAYABO	89 11 13 - 90 02 25	2	106	1920	0.75
A	99	7201	H CARACAS	59 10 31 - 63 07 18	2	1356	32544	
G	84	7201	* CARACAS	88 12 01 - 89 05 19	7	172	3840	0.93
LZ	402	7201	* CARACAS	88 12 02 - 89 03 09	3	99	2112	0.89
L	298	7202	MARACAIBO	78 06 - 78 11			3612	
L	298	7203	D LLANO DEL HATO	78 12 - 79 02			1344	
LZ	402	7250	* BOGOTA	87 11 21 - 88 04 20	14	152	2640	0.73

Directory of Gravimeters in use for Earth Tide Measurements

Instr.			Station	Epoch	g	d	r	e
G	84	7251	* CARTAGENA	87 05 01 - 87 09 27	7	150	3168	0.88
G	84	7252	* IS.SAN ANDRES	87 11 27 - 88 05 19	3	176	4032	0.96
G	84	7253	* CUCUTA	88 05 26 - 88 10 03	6	131	2880	0.92
LZ	402	7254	* CALI	88 05 30 - 88 07 31	2	64	1344	0.88
G	783	7281	* KOUROU	88 11 18 - 89 05 10	3	176	4080	0.97
G	783	7303	* SAO PAULO	91 09 22 - 92 03 25	5	187	4032	0.90
LZ	913	7303	* SAO PAULO	91 05 09 - 92 05 18	16	378	7776	0.86
AB	85/2	7305	* CURITIBA	83 04 16 - 85 04 28	26	746	15456	0.86
ET*	10	7305	* CURITIBA	87 12 05 - 88 06 04	0	194	4656	1.00
G	783	7305	* CURITIBA	83 10 31 - 84 04 25	8	174	3792	0.91
G	783	7305	* CURITIBA	92 04 03 - 92 10 02	5	184	4176	0.95
L	3	7305	* CURITIBA	84 05 23 - 84 07 20	2	60	1344	0.93
LZ	3	7305	* CURITIBA	84 07 29 - 84 10 27	6	92	1824	0.83
L	8	7305	* CURITIBA	84 05 26 - 84 07 22	1	59	1344	0.95
LZ	8	7305	* CURITIBA	84 07 29 - 84 11 09	6	105	1872	0.74
LD	32	7305	* CURITIBA	84 04 30 - 84 07 20	4	83	1728	0.87
LDZ	32	7305	* CURITIBA	84 07 29 - 84 10 27	2	93	1920	0.86
LZ	99	7305	* CURITIBA	85 08 23 - 85 12 07	8	109	2016	0.77
LZ	487	7306	* S.MARIA	88 04 28 - 88 06 09	5	45	720	0.67
LD	32	7306	* S.MARIA	83 11 03 - 84 04 24	10	175	2640	0.63
LZ	3	7307	* C.GRANDE	84 12 12 - 85 07 09	13	210	2544	0.50
L	8	7307	* C.GRANDE	83 11 13 - 84 04 09	6	150	1824	0.51
L	3	7308	D * VICOSA	83 11 03 - 84 05 04	13	186	3504	0.79
L	8	7308	D * VICOSA	86 10 09 - 87 02 20	3	137	3072	0.94
LZ	8	7308	D * VICOSA	86 08 07 - 86 10 03	3	59	816	0.58
G	783	7309	* CUIABA	84 11 25 - 85 07 07	7	225	2208	0.41
G	783	7310	* GOIANIA	84 05 04 - 84 11 17	8	199	3792	0.79
LZ	8	7311	* CAICO	84 12 11 - 85 07 29	9	231	4896	0.89
LZ	487	7312	* P.PRUDENTE	86 11 21 - 87 05 29	8	190	4080	0.89
G	783	7313	* TERESINA	86 07 30 - 87 06 21	17	327	5644	0.72
G	783	7314	* VASSOURAS	87 06 29 - 88 06 10	19	348	4320	0.52
LZ	3	7315	* MANAUS	85 07 19 - 86 03 08	13	234	3840	0.69
G	783	7316	* BELEM	85 07 26 - 86 02 07	9	199	4080	0.86
LZ	8	7317	* SALVADOR	85 08 06 - 86 05 16	14	285	3408	0.50
G	783	7318	* MEDIANEIRA	93 07 23 - 93 08 16	1	26	528	0.86
LZ	913	7319	* VALINHOS	92 10 11 - 93 05 23	12	226	4464	0.82
G	783	7351	* F.NORONHA	91 02 11 - 91 09 15	7	218	3312	0.63
LZ	402	7408	* AREQUIPA	85 03 20 - 85 10 08	9	203	4464	0.92
G	84	7409	* NANA	85 03 31 - 85 10 13	8	197	4176	0.88
LZ	402	7410	* CHICLAYO	85 11 04 - 86 03 24	11	142	2544	0.75
G	84	7411	* IQUITOS	85 10 24 - 86 04 24	2	184	4272	0.97
G	84	7412	* NAZCA	86 05 05 - 86 10 22	6	172	3696	0.90
LZ	402	7450	* QUITO	87 04 24 - 87 09 30	9	161	3264	0.85
G	84	7451	* GUAYAQUIL	86 11 18 - 87 04 20	7	154	2880	0.78
LZ	402	7500	* LA PAZ	86 05 11 - 86 11 02	2	177	4176	0.98
G	84	7505	* SANTA CRUZ 1	84 08 05 - 85 03 13	11	222	1920	0.36
LZ	402	7506	* SANTA CRUZ 2	86 11 19 - 86 12 2	1	34	768	0.94
LZ	402	7601	* IQUIQUE	92 11 15 - 93 02 23	3	102	2256	0.92

Directory of Gravimeters in use for Earth Tide Measurements

Instr.		Station	Epoch	g	d	r	e
G	765	7805 * BUENOS AIRES	90 10 16 - 91 05 21	3	219	5136	0.98
LZ	906	7805 * BUENOS AIRES	88 09 26 - 89 02 27	5	156	3552	0.95
G	765	7810 * TANDIL	88 03 26 - 88 09 06	3	166	3840	0.97
G	765	7812 * PILAR	88 10 01 - 88 12 02	2	64	1296	0.39
G	765	7813 * CORRIENTES	89 03 18 - 89 10 07	6	205	1776	0.36
LZ	906	7814 * ZONDA	89 10 07 - 90 03 27	15	173	2976	0.72
G	765	7815 * S.LORENZO	89 10 16 - 90 03 13	4	151	3360	0.93
G	765	7816 * BARILOCHE	90 03 25 - 90 08 26	4	201	4320	0.90
LZ	906	7817 * USHUAIA	90 04 07 - 90 09 07	7	155	3408	0.92
LZ	906	7818 * C.RIVADAVIA	90 10 07 - 91 05 24	10	238	4608	0.81
G	765	7819 * SANTA ROSA	91 05 30 - 91 12 27	10	212	4560	0.90
LZ	906	7895 * TACUAREMBO	89 03 07 - 89 09 27	8	207	4368	0.88
A*	206	9904 KERGUELEN	73 01 05 - 74 01 28	9	391	8928	0.95
LZ	99	9910 * C.FERRAZ/K.G.	86 02 26 - 87 12 10	44	654	10560	0.67
LZ	589	9911 GREAT WALL/K.G.	88 02 15 - 89 03 01		342		
LZ	805	9941 * ASUKA	87 06 26 - 87 11 13	0	142	3408	1.00
A	137	9955 MOLODJOSHNAJA					
GWRT	16	9960 SYOWA	93 03 19 -				
LZ	477	9960 * SYOWA	87 04 01 - 87 06 01	0	62	1488	1.00
LCR/D	73	9960 SYOWA	92 02 16 - 92 12 23				
LCR/G	515	9960 SYOWA	92 02 16 - 92 09 21				
ET	4	9998 * SOUTH POLE	74 01 02 - 74 03 31	0	90	2160	1.00
ET	6	9998 SOUTH POLE	74 01 - 74 03			2160	

DIRECTORY OF GRAVITY METERS IN USE FOR EARTH TIDE MEASUREMENTS

8 february 1994

PART III: Instrument's Owners

INSTRUMENTS

A - ASKANIA GS 11, GS 12
A* - ASKANIA GS 15
A# - ASKANIA GS 25
AB - ASKANIA modified by M. Bonatz
AD - ASKANIA modified by Dittfeld and Neumeyer
AR - ASKANIA modified by I. Rogatnev

G - GEODYNAMICS

L - LACOSTE ROMBERG model G
LD - LACOSTE ROMBERG model D
LZ - LACOSTE ROMBERG with zero method

ET - LACOSTE ROMBERG Earth Tide/mechanical feedback
ET* - LACOSTE ROMBERG Earth Tide/electronic feedback

GWR - SUPERCONDUCTING gravimeter

UCSD- SGA/B Superconducting gravimeter

Others

Number of instruments listed

Askania	77
Geodynamics	22
LaCoste Romberg	58
ET LaCoste Romberg	18
Superconducting GWR	18
Superconducting UCSD	2
Others	2
Total	197

Part III: Instruments's owners/ index pays

Instr.	Institution	Country	City
AB 155/22	Inst.Geodäsie, Technische Universitat	A	Graz
G 151	Technische Hochschule, Geodaesie	A	Graz
L 9	Inst.für Meteorologie und Geophysik, Univ.	A	Wien
L 398	Bureau of Mineral Resources	AUS	Canberra
AB 143/15	Institut Royal Météorologique de Belgique	B	Bruxelles
AB 145/9	Observatoire Royal de Belgique	B	Bruxelles
AB 160/3	Observatoire Royal de Belgique	B	Bruxelles
AB 175/13	Observatoire Royal de Belgique	B	Bruxelles
AB 191/1	Observatoire Royal de Belgique	B	Bruxelles
G 74	Université	B	Liège
G 84	Observatoire Royal de Belgique	B	Bruxelles
G 765	Observatoire Royal de Belgique	B	Bruxelles
G 783	Observatoire Royal de Belgique	B	Bruxelles
GWRT003	Observatoire Royal de Belgique	B	Bruxelles
LZ 3	Observatoire Royal de Belgique	B	Bruxelles
LZ 8	Observatoire Royal de Belgique	B	Bruxelles
L 31	Universités de Liège et Louvain L.N.	B	Louvain L.N.
LD 32	Institut Géographique National	B	Bruxelles
LZ 336	Observatoire Royal de Belgique	B	Bruxelles
LZ 402	Observatoire Royal de Belgique	B	Bruxelles
LZ 487	Observatoire Royal de Belgique	B	Bruxelles
LZ 906	Observatoire Royal de Belgique	B	Bruxelles
LZ 99	Politecnico/Universidade Federal do Parana	BR	Curitiba
LZ 913	Instituto Astronomico e Geofisico, Universidad	BR	Sao Paulo
ET 12	Geophysics Division/ Geological Survey	CDN	Ottawa
GWRT012	Mc Gill University	CND	Ottawa
AB 79/12	Deutsches Geodätisches F.Inst.	D	München
AB 85/2	Institut für Theoretische Geodaesie	D	Bonn
A 98	Institut für Theoretische Geodaesie	D	Bonn
A 116	Institut für Theoretische Geodaesie	D	Bonn
AB 130/5	Institut für Erdmessung, Universitaet	D	Hannover
A 137	GeoForschungsZentrum	D	Potsdam
AB 138/6	Geodaetisches Institut	D	Karlsruhe
A 162	GeoForschungsZentrum	D	Potsdam
AD 188	GeoForschungsZentrum	D	Potsdam
A* 204	Geophysikalisches Institut, Universitaet	D	Kiel
A* 206	Institut für Theoretische Geodaesie	D	Bonn
A* 210	Geophysikalisches Institut, Universitaet	D	Kiel
A* 219	Geophysikalisches Institut, Universitaet	D	Kiel
A* 222	GeoforschungsZentrum	D	Potsdam
A# 233	Institut für Theoretische Geodaesie	D	Bonn
ET* 16	Institut für Physikalische Geodäsie	D	Darmstadt
ET* 18	Institut für Geophysik	D	Clausthal
ET* 19	Black Forest Observatory	D	Schiltach
GWRT001	Institut für Angewandte Geodaesie	D	Frankfurt
GWRT006	Institut für Angewandte Geodaesie	D	Wettzel
GWRT008	Gesellschaft für Strahlenundumwelt-Forschung	D	Braunschweig
GWRT018	GeoForschungsZentrum	D	Potsdam
GWRT101	Institut für Angewandte Geodaesie	D	Frankfurt
GWRT103	Institut für Angewandte Geodaesie	D	Frankfurt
LDZ 8	Institut für Geophysik	D	Clausthal
LDZ 14	Institut für Erdmessung, Universitaet	D	Hannover
L 58	Institut für Angewandte Geodaesie	D	Frankfurt
LZ 79	GeoForschungsZentrum	D	Potsdam
LZ 87	DGFI Abt. 1	D	München
L 98	Institut für Angewandte Geodaesie	D	Frankfurt
L 140	Institut für Angewandte Geodaesie	D	Frankfurt
LZ 156	Geodaetisches Institut, Universitaet	D	Karlsruhe
L 195	Technische Universität	D	München
LZ 249	Geodaetisches Institut, Universitaet	D	Karlsruhe
L 258	Institut für Physikalische Geodäsie	D	Darmstadt
L 260	Institut für Geophysik, Universitaet	D	Hamburg
L 298	Institut für Erdmessung, Universitaet	D	Hannover

LZ 299	Institut für Angewandte Geodaesie	D	Frankfurt
L 318	Institut fuer Hoehere Geodaesie	D	Berlin
LZ 709	Geodaetisches Institut, Universitaet	D	Karlsruhe
LZ 995	GeoForschungsZentrum	D	Potsdam
A* 212	Instituto de Astronomia y Geodesia	E	Madrid
L 301	Instituto de Astronomia y Geodesia	E	Madrid
L 434	Instituto de Astronomia y Geodesia	E	Madrid
LZ 665	Instituto de Astronomia y Geodesia	E	Madrid
A 147	Institute of Geology	EST	Tallinn
ET 5	Institut de Physique du Globe	F	Strasbourg
ET 8	Institut de Physique du Globe	F	Strasbourg
GWRT005	Institut de Physique du Globe	F	Strasbourg
GWRT0??	The Finnish Geodetic Institute	F	Helsinki
LZ 601	Institut de Physique du Globe	F	Paris
NA 138	Institut de Physique du Globe	F	Strasbourg
WES/SAK	BIPM	F	Sèvres
GWRT017	University of Thessaloniki	G	Thessaloniki
ET* 10	Proudman Oceanographic Laboratory	GB	Bidston
ET* 13	Proudman Oceanographic Laboratory	GB	Bidston
ET* 15	Proudman Oceanographic Laboratory	GB	Bidston
AB 144	Institute of Geophysics	GEO	Tbilisi
A 166	Institute of Geophysics	GEO	Tbilisi
LZ 265	Dept.of Geodesy, University	GR	Thessaloniki
A 190/7	Geophysical Institute Eötvös, University	H	Budapest
A* 224	Geophysical Institute Eötvös, University	H	Budapest
A 97	Istituto di Geodesia, Università	I	Genova
A 108	Istituto di Geodesia, Università	I	Padova
AB 108/10	Istituto di Geodesia, Università	I	Padova
A 120	Istituto di Geodesia	I	Palermo
AB 122/21	Istituto di Geodesia e Geofisica	I	Trieste
A 141	Osservatorio Vesuviano	I	Napoli
GWRT015	Istituto Nazionale di Fisica Nucleare	I	Bologna
LDZ126	Osservatorio Vesuviano	I	Napoli
A 25	Institut de Géophysique, Université	IR	Téhéran
AB 119/25	Institut de Géophysique, Université	IR	Téhéran
A 105	National Astronomical Observatory	J	Mizusawa
A 111	Department of Geophysics, University	J	Kyoto
A 193	National Astronomical Observatory	J	Mizusawa
A 197	National Astronomical Observatory	J	Mizusawa
A* 217	Department of Geophysics, University	J	Kyoto
ET 17	Meteorological Research Institute	J	Tsukuba
G 163	National Astronomical Observatory	J	Mizusawa
GWRT007	National Astronomical Observatory	J	Mizusawa
GWRT009	Department of Geophysics, University	J	Kyoto
GWRT010	Department of Geophysics, University	J	Kyoto
GWRT011	Ocean Research Institute, University	J	Tokyo
GWRT016	National Astronomical Observatory	J	Syowa /Antarctica
L 29	Earthquake Research Institute, University	J	Tokyo
L 34	Earthquake Research Institute, University	J	Tokyo
LD 58	Geophysical Institute, University	J	Kyoto
LD 63	Earthquake Research Institute	J	Tokyo
L 124	Ocean Research Institute, University	J	Tokyo
L 304	National Astronomical Observatory	J	Mizusawa
L 305	National Astronomical Observatory	J	Mizusawa
L 308	National Astronomical Observatory	J	Mizusawa
LZ 447	Earthquake Research Institute	J	Tokyo
LZ 457	National Astronomical Observatory	J	Mizusawa
LZ 477	National Institute of Polar Research	J	Tokyo
L 680	Geophysical Institute, University	J	Kyoto
LZ 805	National Institute of Polar Research	J	Tokyo
LDZ 44	Universidad Nacional	MEX	Mexico
LD 59	Koninklijk Nederlands Meteorologisch Inst.	NL	Utrecht
G 31	Victoria University	NZ	Wellington
L 179	Victoria University	NZ	Wellington
AB 110/17	Space Research Centre	PL	Warszawa
A 112	Space Research Centre	PL	Warszawa
AB 165/14	Institut Géophysique	RO	Bucarest

AB 171/4	Institut Géophysique	RO	Bucarest
AB 173/24	Institut Géophysique	RO	Bucarest
AB 176/8	Institut Géophysique	RO	Bucarest
AB 177/16	Institut Géophysique	RO	Bucarest
A 126	Institute of Physics of the Earth	RUS	Moscow
A 134	Institute of Physics of the Earth	RUS	Moscow
AB 135/19	Institute of Physics of the Earth	RUS	Moscow
A 167	Institute of Seismology	RUS	Moscow
A 186	Institute of Geology and Geophysics	RUS	Novosibirsk
A* 220	Institute of Physics of the Earth	RUS	Moscow
A* 221	Institute of Physics of the Earth	RUS	Moscow
AB 168/18	Institutionen for Geodesi	S	Stockholm
AB 198/23	National Land Survey	S	Gävle
AB 202/11	Geophysical Institute	S	Uppsala
AB 187/20	Geodeettinen Laitos	SF	Helsinki
LZ 600	Geodeettinen Laitos	SF	Helsinki
A* 226	Royal Thai Survey Department	T	Bangkok
AD 131	Res.Inst.of Geodesy, Topography & Cartogr.	TCH	Praha
AB 133/27	Geophysical Institute, Czech Acad.Sciences	TCH	Praha
AB 201/26	Res.Inst.of Geodesy, Topography & Cartogr.	TCH	Praha
A* 228	Technical University	TCH	Praha
A 149	Institute of Geodesy and Geophysics	TJ	Wuhan
A* 205	Seismological Bureau of Henan Province	TJ	Zhengzhou
A* 211	Seismological Bureau of Yunnan Province	TJ	Kunming
A* 213	Seismological Bureau of Sichan Province	TJ	Pixian
A* 215	Seismological Bureau of Ningxia	TJ	Yinchan
A* 218	Seismological Bureau of Xinjiang	TJ	Urumqi
A* 227	Institute of Seismology, SSB	TJ	Wuhan
A* 229	Seismological Bureau of Sichan Province	TJ	Dukou
A* 230	Seismological Bureau of Yunnan Province	TJ	Midu
A* 231	Institute of Geology	TJ	Beijing
A* 232	Seismological Bureau of Tianjin City	TJ	Baodi
ET 20	Institute of Geodesy and Geophysics	TJ	Wuhan
ET 21	Institute of Geodesy and Geophysics	TJ	Wuhan
ET 22	Institute of Seismology, SSB	TJ	Wuhan
GWRT004	Institute of Geodesy & Geophysics	TJ	Chine
LZ 584	Institute of Geodesy and Geophysics	TJ	Wuhan
LZ 589	Institute of Geodesy and Geophysics	TJ	Wuhan
A 159	Observatoire Gravimétrique	UKR	Poltava
A 185	Observatoire Gravimétrique	UKR	Poltava
ET* 2	Institute of Geophysics UCLA	USA	Los Angeles
ET* 4	Institute of Geophysics UCLA	USA	Los Angeles
ET* 6	Institute of Geophysics UCLA	USA	Los Angeles
ET* 7	Institute of Geophysics UCLA	USA	Los Angeles
ET* 11	Institute of Geophysics UCLA	USA	Los Angeles
G 17	Virginia Polytechnic Inst.and State Univ.	USA	Blacksburg
G 703	Lamont Doherty Geological Observatory	USA	New York
G 710	Lamont Doherty Geological Observatory	USA	New York
G 718	Lamont Doherty Geological Observatory	USA	New York
G 721	Lamont Doherty Geological Observatory	USA	New York
G 728	Lamont Doherty Geological Observatory	USA	New York
G 730	Lamont Doherty Geological Observatory	USA	New York
G 735	Virginia Polytechnic Inst.and State Univ.	USA	Blacksburg
G 761	D.M.A.:on loan ->Geod.Laitos/Helsinki 1971-81	USA	Washington
G 761	D.M.A.:on loan ->Virginia Polytechnic Inst.	USA	Washington
G 786	D.M.A.:on loan ->Virginia Polytechnic Inst.	USA	Washington
G 804	Lamont Doherty Geological Observatory	USA	New York
G 826	Virginia Polytechnic Inst.and State Univ.	USA	Blacksburg
G 832	Lamont Doherty Geological Observatory	USA	New York
G 834	Lamont Doherty Geological Observatory	USA	New York
L 2	Institute of Geophysics UCLA	USA	Los Angeles
L 4	Institute of Geophysics UCLA	USA	Los Angeles
LZ 612	Virginia Polytechnic Inst.and State Univ.	USA	Blacksburg
L 826	Virginia Polytechnic Inst.and State Univ.	USA	Blacksburg
UCSD/SGA	University of California, San Diego	USA	San Diego
UCSD/SGB	University of California, San Diego	USA	Fairbanks, Alaska
A 99	Observatorio Cagigal	VZ	Caracas

Part III: Instruments's owners/ index instruments

Instr.	Institution	Country	City
A 25	Institut de Géophysique, Université	IR	Téhéran
AB 79/12	Deutsches Geodätisches F.Inst.	D	München
AB 85/2	Institut für Theoretische Geodaesie	D	Bonn
A 97	Istituto di Geodesia, Università	I	Genova
A 98	Institut für Theoretische Geodaesie	D	Bonn
A 99	Observatorio Cagigal	VZ	Caracas
A 105	National Astronomical Observatory	J	Mizusawa
A 108	Istituto di Geodesia, Università	I	Padova
AB 108/10	Istituto di Geodesia, Università	I	Padova
AB 110/17	Space Research Centre	PL	Warszawa
A 111	Department of Geophysics, University	J	Kyoto
A 112	Space Research Centre	PL	Warszawa
A 116	Institut für Theoretische Geodaesie	D	Bonn
AB 119/25	Institut de Géophysique, Université	IR	Téhéran
A 120	Istituto di Geodesia	I	Palermo
AB 122/21	Istituto di Geodesia e Geofisica	I	Trieste
A 126	Institute of Physics of the Earth	RUS	Moscow
AB 130/5	Institut für Erdmessung, Universitaet	D	Hannover
AD 131	Res.Inst.of Geodesy, Topography & Cartogr.	TCH	Praha
AB 133/27	Geophysical Institute, Czech Acad.Sciences	TCH	Praha
A 134	Institute of Physics of the Earth	RUS	Moscow
AB 135/19	Institute of Physics of the Earth	RUS	Moscow
A 137	GeoForschungsZentrum	D	Potsdam
AB 138/6	Geodaetisches Institut	D	Karlsruhe
A 141	Osservatorio Vesuviano	I	Napoli
AB 143/15	Institut Royal Météorologique de Belgique	B	Bruxelles
AB 144	Institute of Geophysics	GEO	Tbilisi
AB 145/9	Observatoire Royal de Belgique	B	Bruxelles
A 147	Institute of Geology	EST	Tallinn
A 149	Institute of Geodesy and Geophysics	TJ	Wuhan
AB 155/22	Inst.Geodäsie, Technische Universitat	A	Graz
A 159	Observatoire Gravimétrique	UKR	Poltava
AB 160/3	Observatoire Royal de Belgique	B	Bruxelles
A 162	GeoForschungsZentrum	D	Potsdam
AB 165/14	Institut Géophysique	RO	Bucarest
A 166	Institute of Geophysics	GEO	Tbilisi
A 167	Institute of Seismology	RUS	Moscow
AB 168/18	Institutionen for Geodesi	S	Stockholm
AB 171/4	Institut Géophysique	RO	Bucarest
AB 173/24	Institut Géophysique	RO	Bucarest
AB 175/13	Observatoire Royal de Belgique	B	Bruxelles
AB 176/8	Institut Géophysique	RO	Bucarest
AB 177/16	Institut Géophysique	RO	Bucarest
A 185	Observatoire Gravimétrique	UKR	Poltava
A 186	Institute of Geology and Geophysics	RUS	Novosibirsk
AB 187/20	Geodeettinen Laitos	SF	Helsinki
AD 188	GeoForschungsZentrum	D	Potsdam
A 190/7	Geophysical Institute Eötvös, University	H	Budapest
AB 191/1	Observatoire Royal de Belgique	B	Bruxelles
A 193	National Astronomical Observatory	J	Mizusawa
A 197	National Astronomical Observatory	J	Mizusawa
AB 198/23	National Land Survey	S	Gävle
AB 201/26	Res.Inst.of Geodesy, Topography & Cartogr.	TCH	Praha
AB 202/11	Geophysical Institute	S	Uppsala
A* 204	Geophysikalisches Institut, Universitaet	D	Kiel
A* 205	Seismological Bureau of Henan Province	TJ	Zhengzhou
A* 206	Institut für Theoretische Geodaesie	D	Bonn
A* 210	Geophysikalisches Institut, Universitaet	D	Kiel
A* 211	Seismological Bureau of Yunnan Province	TJ	Kunming
A* 212	Instituto de Astronomia y Geodesia	E	Madrid
A* 213	Seismological Bureau of Sichan Province	TJ	Pixian
A* 215	Seismological Bureau of Ningxia	TJ	Yinchan
A* 217	Department of Geophysics, University	J	Kyoto

A* 218	Seismological Bureau of Xinjiang	TJ	Urumqi
A* 219	Geophysikalisches Institut, Universitaet	D	Kiel
A* 220	Institute of Physics of the Earth	RUS	Moscow
A* 221	Institute of Physics of the Earth	RUS	Moscow
A* 222	GeoforschungsZentrum	D	Potsdam
A* 224	Geophysical Institute Eötvös, University	H	Budapest
A* 226	Royal Thai Survey Department	T	Bangkok
A* 227	Institute of Seismology, SSB	TJ	Wuhan
A* 228	Technical University	TCH	Praha
A* 229	Seismological Bureau of Sichan Province	TJ	Dukou
A* 230	Seismological Bureau of Yunnan Province	TJ	Midu
A* 231	Institute of Geology	TJ	Beijing
A* 232	Seismological Bureau of Tianjin City	TJ	Baodi
A# 233	Institut für Theoretische Geodaesie	D	Bonn
ET* 2	Institute of Geophysics UCLA	USA	Los Angeles
ET* 4	Institute of Geophysics UCLA	USA	Los Angeles
ET 5	Institut de Physique du Globe	F	Strasbourg
ET* 6	Institute of Geophysics UCLA	USA	Los Angeles
ET* 7	Institute of Geophysics UCLA	USA	Los Angeles
ET 8	Institut de Physique du Globe	F	Strasbourg
ET* 10	Proudman Oceanographic Laboratory	GB	Bidston
ET* 11	Institute of Geophysics UCLA	USA	Los Angeles
ET 12	Geophysics Division/ Geological Survey	CDN	Ottawa
ET* 13	Proudman Oceanographic Laboratory	GB	Bidston
ET* 15	Proudman Oceanographic Laboratory	GB	Bidston
ET* 16	Institut für Physikalische Geodäsie	D	Darmstadt
ET 17	Meteorological Research Institute	J	Tsukuba
ET* 18	Institut für Geophysik	D	Clausthal
ET* 19	Black Forest Observatory	D	Schiltach
ET 20	Institute of Geodesy and Geophysics	TJ	Wuhan
ET 21	Institute of Geodesy and Geophysics	TJ	Wuhan
ET 22	Institute of Seismology, SSB	TJ	Wuhan
G 17	Virginia Polytechnic Inst.and State Univ.	USA	Blacksburg
G 31	Victoria University	NZ	Wellington
G 74	Université	B	Liège
G 84	Observatoire Royal de Belgique	B	Bruxelles
G 151	Technische Hochschule, Geodaesie	A	Graz
G 163	National Astronomical Observatory	J	Mizusawa
G 703	Lamont Doherty Geological Observatory	USA	New York
G 710	Lamont Doherty Geological Observatory	USA	New York
G 718	Lamont Doherty Geological Observatory	USA	New York
G 721	Lamont Doherty Geological Observatory	USA	New York
G 728	Lamont Doherty Geological Observatory	USA	New York
G 730	Lamont Doherty Geological Observatory	USA	New York
G 735	Virginia Polytechnic Inst.and State Univ.	USA	Blacksburg
G 761	D.M.A.:on loan ->Geod.Laitos/Helsinki 1971-81	USA	Washington
G 761	D.M.A.:on loan ->Virginia Polytechnic Inst.	USA	Washington
G 765	Observatoire Royal de Belgique	B	Bruxelles
G 783	Observatoire Royal de Belgique	B	Bruxelles
G 786	D.M.A.:on loan ->Virginia Polytechnic Inst.	USA	Washington
G 804	Lamont Doherty Geological Observatory	USA	New York
G 826	Virginia Polytechnic Inst.and State Univ.	USA	Blacksburg
G 832	Lamont Doherty Geological Observatory	USA	New York
G 834	Lamont Doherty Geological Observatory	USA	New York
GWRT001	Institut für Angewandte Geodaesie	D	Frankfurt
GWRT003	Observatoire Royal de Belgique	B	Bruxelles
GWRT004	Institute of Geodesy & Geophysics	TJ	Chine
GWRT005	Institut de Physique du Globe	F	Strasbourg
GWRT006	Institut für Angewandte Geodaesie	D	Wettzel
GWRT007	National Astronomical Observatory	J	Mizusawa
GWRT008	Gesellschaft für Strahlenundumwelt-Forschung	D	Braunschweig
GWRT009	Department of Geophysics, University	J	Kyoto
GWRT010	Department of Geophysics, University	J	Kyoto
GWRT011	Ocean Research Institute, University	J	Tokyo
GWRT012	Mc Gill University	CND	Ottawa
GWRT015	Istituto Nazionale di Fisica Nucleare	I	Bologna
GWRT016	National Astronomical Observatory	J	Syowa /Antarctica

GWRT017	University of Thessaloniki	G	Thessaloniki
GWRT018	GeoForschungsZentrum	D	Potsdam
GWRT0??	The Finnish Geodetic Institute	F	Helsinki
GWRT101	Institut für Angewandte Geodaesie	D	Frankfurt
GWRT103	Institut für Angewandte Geodaesie	D	Frankfurt
L 2	Institute of Geophysics UCLA	USA	Los Angeles
LZ 3	Observatoire Royal de Belgique	B	Bruxelles
L 4	Institute of Geophysics UCLA	USA	Los Angeles
LDZ 8	Institut für Geophysik	D	Clausthal
LZ 8	Observatoire Royal de Belgique	B	Bruxelles
L 9	Inst.für Meteorologie und Geophysik, Univ.	A	Wien
LDZ 14	Institut für Erdmessung, Universitaet	D	Hannover
L 29	Earthquake Research Institute, University	J	Tokyo
L 31	Universités de Liège et Louvain L.N.	B	Louvain L.N.
LD 32	Institut Géographique National	B	Bruxelles
L 34	Earthquake Research Institute, University	J	Tokyo
LDZ 44	Universidad Nacional	MEX	Mexico
L 58	Institut für Angewandte Geodaesie	D	Frankfurt
LD 58	Geophysical Institute, University	J	Kyoto
LD 59	Koninklijk Nederlands Meteorologisch Inst.	NL	Utrecht
LD 63	Earthquake Research Institute	J	Tokyo
LZ 79	GeoForschungsZentrum	D	Potsdam
LZ 87	DGFI Abt. 1	D	München
L 98	Institut für Angewandte Geodaesie	D	Frankfurt
LZ 99	Politecnico/Universidade Federal do Parana	BR	Curitiba
L 124	Ocean Research Institute, University	J	Tokyo
LDZ126	Osservatorio Vesuviano	I	Napoli
L 140	Institut für Angewandte Geodaesie	D	Frankfurt
LZ 156	Geodaetisches Institut, Universitaet	D	Karlsruhe
L 179	Victoria University	NZ	Wellington
L 195	Technische Universität	D	München
LZ 249	Geodaetisches Institut, Universitaet	D	Karlsruhe
L 258	Institut für Physikalische Geodäsie	D	Darmstadt
L 260	Institut für Geophysik, Universitaet	D	Hamburg
LZ 265	Dept.of Geodesy, University	GR	Thessaloniki
L 298	Institut für Erdmessung, Universitaet	D	Hannover
LZ 299	Institut für Angewandte Geodaesie	D	Frankfurt
L 301	Instituto de Astronomia y Geodesia	E	Madrid
L 304	National Astronomical Observatory	J	Mizusawa
L 305	National Astronomical Observatory	J	Mizusawa
L 308	National Astronomical Observatory	J	Mizusawa
L 318	Institut fuer Hoehere Geodaesie	D	Berlin
LZ 336	Observatoire Royal de Belgique	B	Bruxelles
L 398	Bureau of Mineral Resources	AUS	Canberra
LZ 402	Observatoire Royal de Belgique	B	Bruxelles
L 434	Instituto de Astronomia y Geodesia	E	Madrid
LZ 447	Earthquake Research Institute	J	Tokyo
LZ 457	National Astronomical Observatory	J	Mizusawa
LZ 477	National Institute of Polar Research	J	Tokyo
LZ 487	Observatoire Royal de Belgique	B	Bruxelles
LZ 584	Institute of Geodesy and Geophysics	TJ	Wuhan
LZ 589	Institute of Geodesy and Geophysics	TJ	Wuhan
LZ 600	Geodeettinen Laitos	SF	Helsinki
LZ 601	Institut de Physique du Globe	F	Paris
LZ 612	Virginia Polytechnic Inst.and State Univ.	USA	Blacksburg
LZ 665	Instituto de Astronomia y Geodesia	E	Madrid
L 680	Geophysical Institute, University	J	Kyoto
LZ 709	Geodaetisches Institut, Universitaet	D	Karlsruhe
LZ 805	National Institute of Polar Research	J	Tokyo
L 826	Virginia Polytechnic Inst.and State Univ.	USA	Blacksburg
LZ 906	Observatoire Royal de Belgique	B	Bruxelles
LZ 913	Instituto Astronomico e Geofisico, Universidad	BR	Sao Paulo
LZ 995	GeoForschungsZentrum	D	Potsdam
NA 138	Institut de Physique du Globe	F	Strasbourg
UCSD/SGA	University of California, San Diego	USA	San Diego
UCSD/SGB	University of California, San Diego	USA	Fairbanks, Alaska
WES/SAK	BIPM	F	Sèvres