

Manfred Bonatz

The Program-Package *GeoDyn16k* for Detailed Analysis of Gravimetric Time Series

Extended Abstract

In terms of metrology, the mechanical sensor of a **static gravimeter** is an **analogue/analogue** converter; e.g. a change of gravity is converted into the change of the position of a test mass suspended on a spring, meaning the transformation of a physical into a geometrical quantity. That basic converter is called the *gravimetric sensor*.

Following up, for position indication a second analogue/analogue converter (transducer) is connected to transform the geometrical input into an electrical output which now again can be converted into a digital readout.

However, one has to recognise that it is the performance and property of the **mechanical sensor** which finally controls the possible performance of the complete measurement device.

It is one of the major tasks of metrology to achieve, that on the way from the basic converter (gravimetric sensor) until the final (analogue or digital) readout no significant loss of accuracy occurs, by either avoiding or modelling and considering instrumental bias.

Additionally it has to be taken into account that the gravimeter sensor reacts not only to variations of the physical quantity to be measured (gravity) but more or less to other quantities too such as temperature, magnetic and electrostatic forces, air pressure etc.

The higher the resolution of a measurement the more complicated it is to reach the goal mentioned before.

One of the basic requirements in that context is the disposability of efficient, problem oriented and flexible systems for data acquisition, data visualisation and data evaluation/analysis.

Within the research activities of the Geodynamical Observatory of the Bonn University (GeoObservatorium Odendorf) a corresponding program system was developed by Marc Eschmann, called *GeoDyn16k*. It was published in: *Marc Eschmann, Experimentelle und numerische Untersuchungen gravimetrischer Gezeitenparameter im GeoObservatorium Odendorf, Dissertation, Bonn 2007* (<http://hss.ulb.uni-bonn.de/2007/1259/1259.htm>).

Meanwhile, during several years the package has been intensively and successfully applied in the frame of multifarious projects.

The GeoDyn16k-program package is composed of three main components:

- Data acquisition** (for application of a high performance 16bit/16channel A/D-converter),
- Data visualisation,**
- Data evaluation and analysis.**

The main features of the components will be described and demonstrated. The performance of the program is illustrated by means of several relevant gravimetric examples.

The component *Data Acquisition*

Messwertregistrierung

Channel	Value	Color
Kanal 1	3,8470 V	Black
Kanal 2	2,2976 V	Brown
Kanal 3	4,1028 V	Red
Kanal 4	3,9606 V	Orange
Kanal 5	1,8254 V	Yellow
Kanal 6	1,7050 V	Green
Kanal 7	3,4323 V	Cyan
Kanal 8	4,5200 V	Blue
Kanal 9	1,8412 V	Dark Blue
Kanal 10		
Kanal 11		
Kanal 12		
Kanal 13		
Kanal 14		
Kanal 15		
Kanal 16		

Samplingrate in Sekunden: 1

☒ Einzelwerte speichern ☒ Minutenmittel bilden ☐ Auto-Wiederaufnahme

unipolar 0..+ ☒ bipolar +/- ☐ 10V ☐ 5V ☐ 2,5V

Auto TSoft Export: Kein TSoft-Export

Anzahl zu messende Werte:

1. DB: Messung_2010_06_13_18_29_DB1.mdb 308877 Werte

Messwert vom 17.06.2010 08:18:26 5147 Mittel

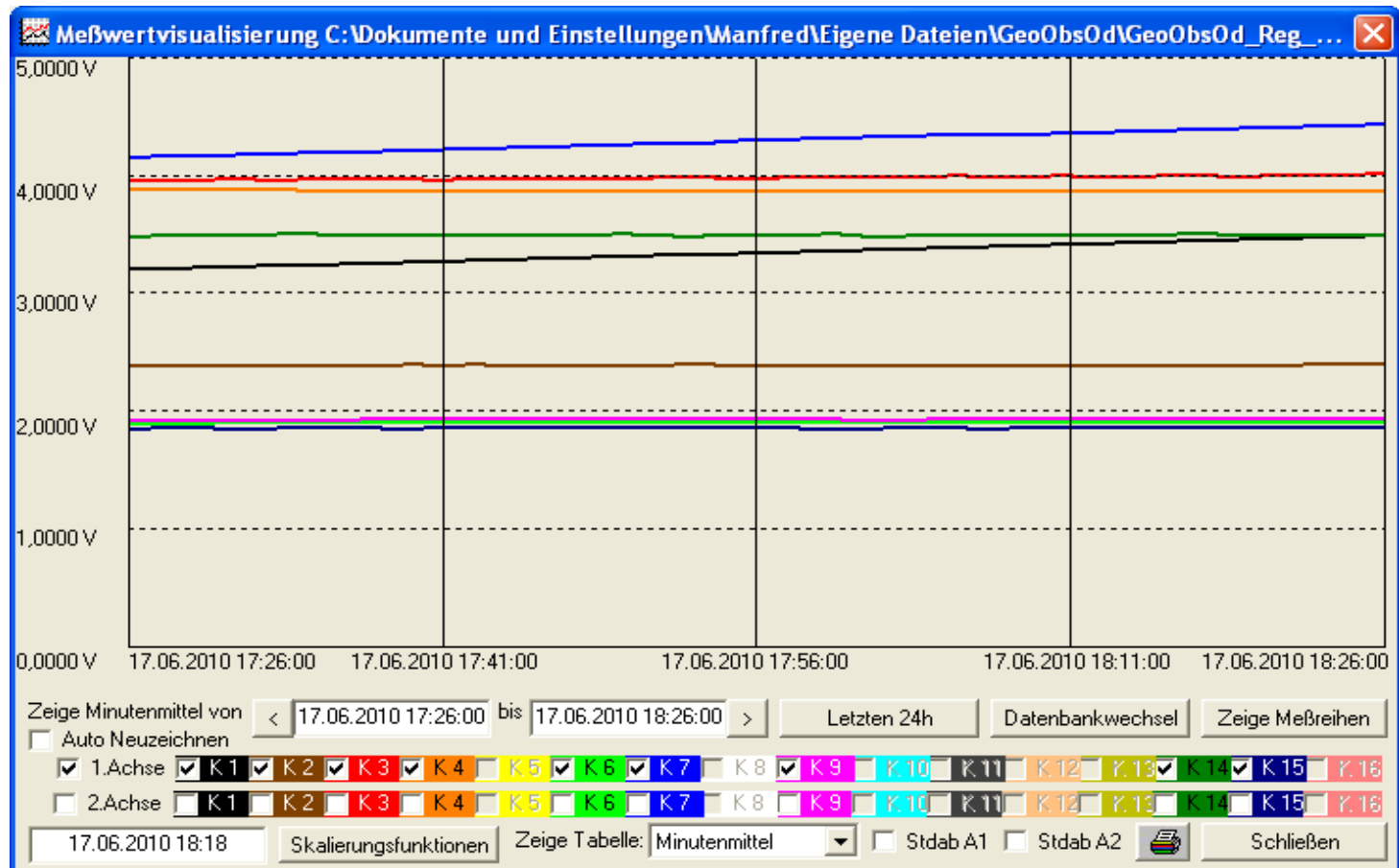
Starten Diagramm

Meßwertüberwachung Schließen

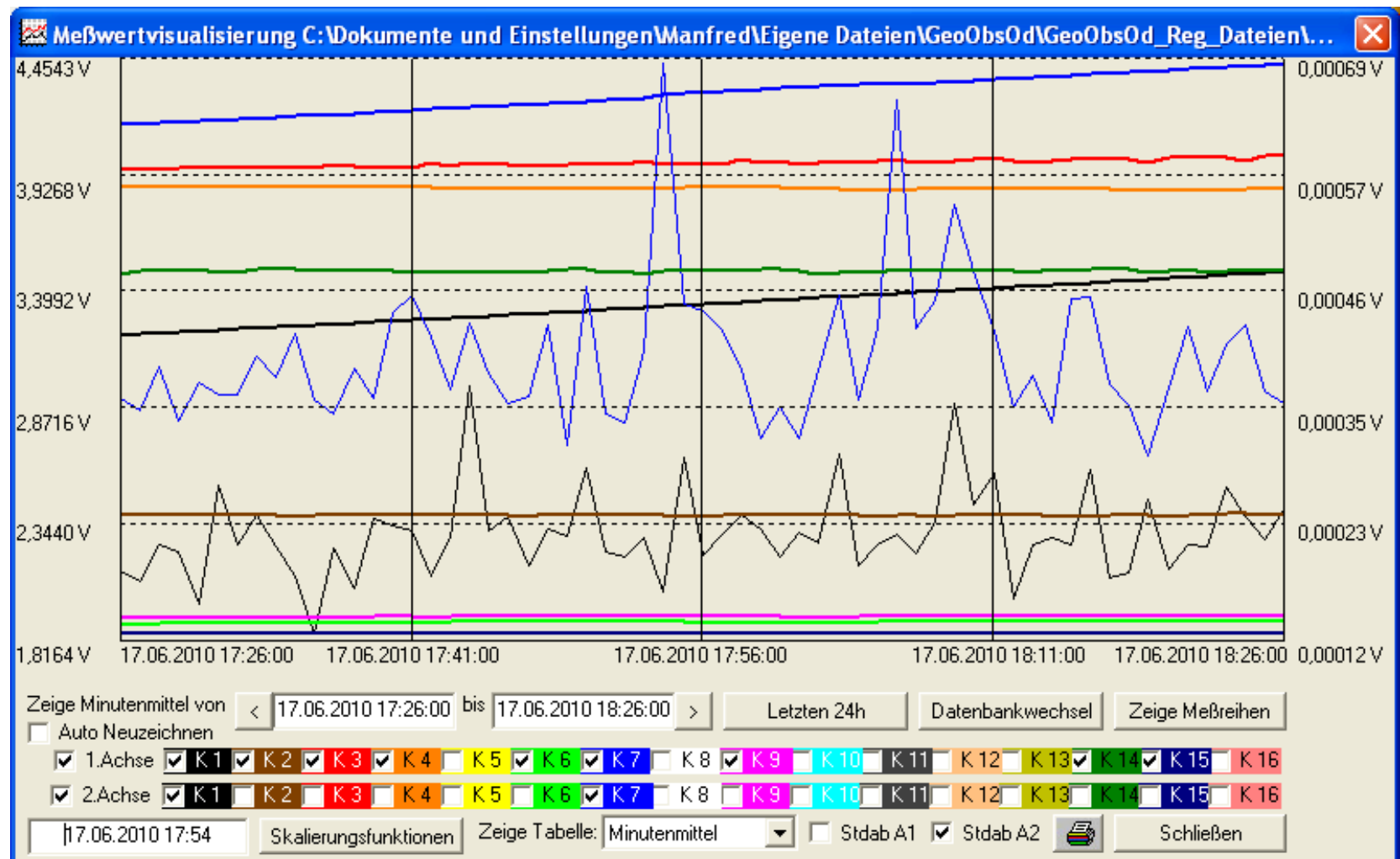
Channel	Alarm Aktiv	Minimum	Maximum
Kanal 1	<input checked="" type="checkbox"/>	0,5	4,5
Kanal 2	<input checked="" type="checkbox"/>	0,2	4,8
Kanal 3	<input checked="" type="checkbox"/>	0,1	4,9
Kanal 4	<input checked="" type="checkbox"/>	0,2	4,8
Kanal 5	<input type="checkbox"/>	0,2	4,8
Kanal 6	<input checked="" type="checkbox"/>	0,2	4,8
Kanal 7	<input type="checkbox"/>	0,5	4,5
Kanal 8	<input type="checkbox"/>	0,1	4,9
Kanal 9	<input type="checkbox"/>	0,1	4,8
Kanal 10	<input type="checkbox"/>	0,1	4,9
Kanal 11	<input type="checkbox"/>	0,1	4,9
Kanal 12	<input type="checkbox"/>	0,1	4,9
Kanal 13	<input type="checkbox"/>	0,1	4,9
Kanal 14	<input checked="" type="checkbox"/>	0,1	4,9
Kanal 15	<input checked="" type="checkbox"/>	0,1	4,9
Kanal 16	<input type="checkbox"/>	0,1	4,9

Sampling rate of signal digitalisation selectable, down to 0,001sec, standard 1sec. Option of setting a measurement interval (number of data to be measured); if no indication after 16 days (file length 907 MB) without gap automatically start of a new file for better handling of long observation series (setup: record and saving of single values and means with standard errors, sampling rate 1sec).

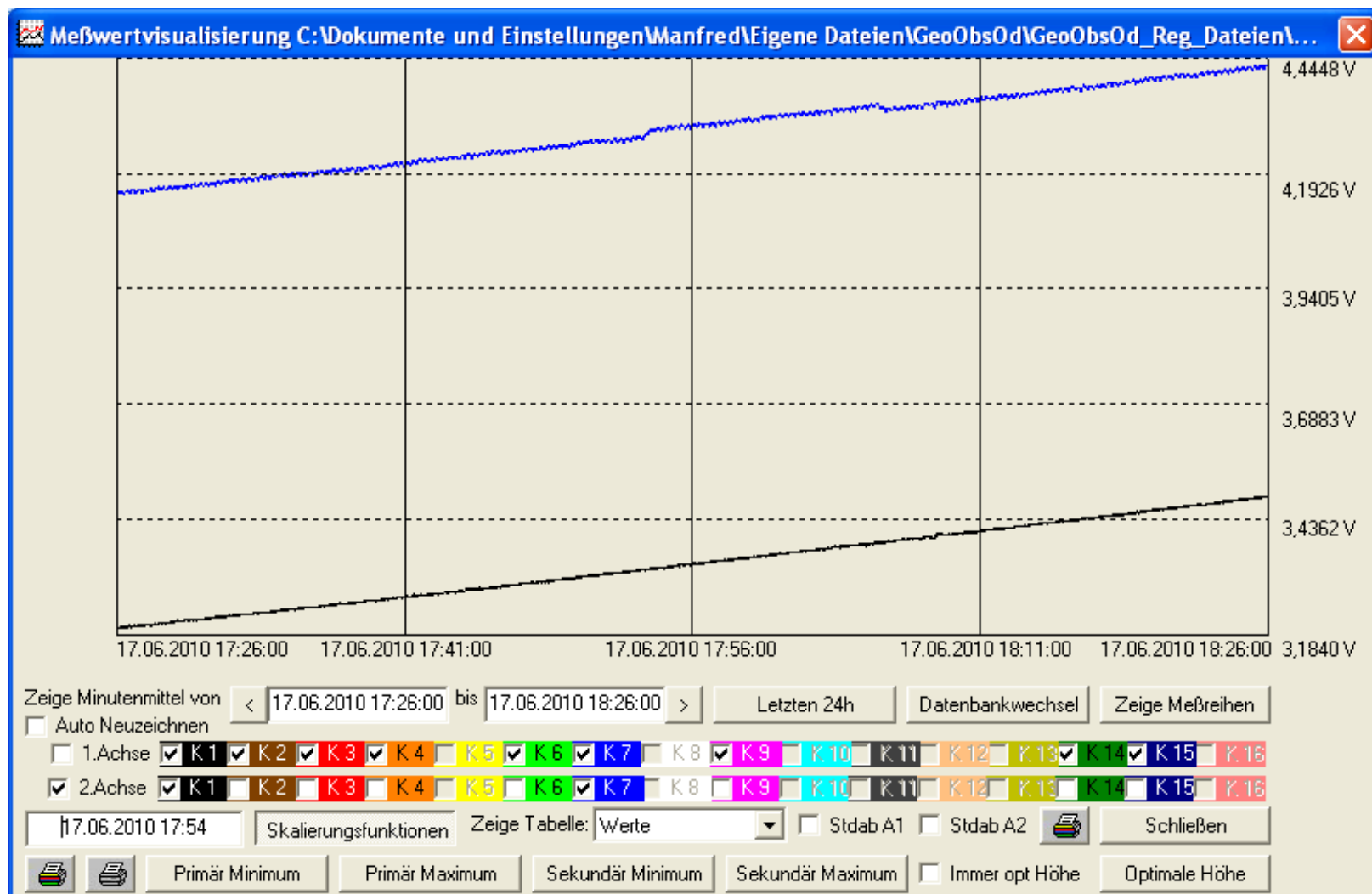
An acoustical alarm can for any channel optionally be activated when the measurement exceeds or falls below a tuned value.



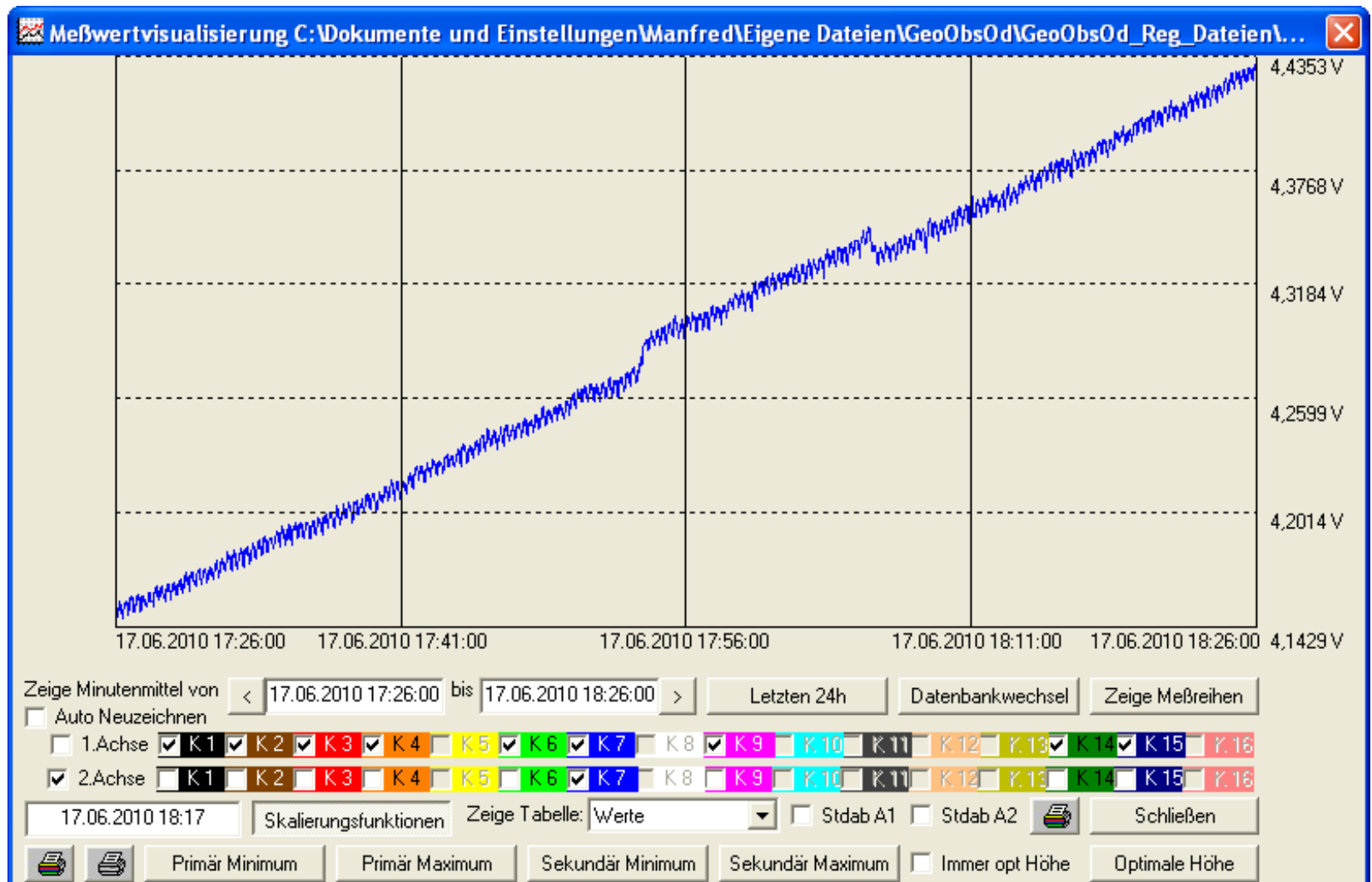
Current real time diagram, update every minute, display interval arbitrary (standard one hour), display option: current run of *single values* or *minute means* with associated standard errors (for intervals from full minute minus 30sec until full minute plus 29sec) to be displayed alternatively in a one-ordinate or two-ordinate diagram. The time corresponding to the position of the mouse cursor inside of the diagram is indicated in the field down left; pushing the left mouse button the left ordinate value, pushing the right mouse button the right ordinate value occurs (if the right ordinate option is activated). Resolution can be controlled by scaling both in time and ordinates.



The parallel display of signal means and associated standard errors
(here for two selected gravimeter channels).

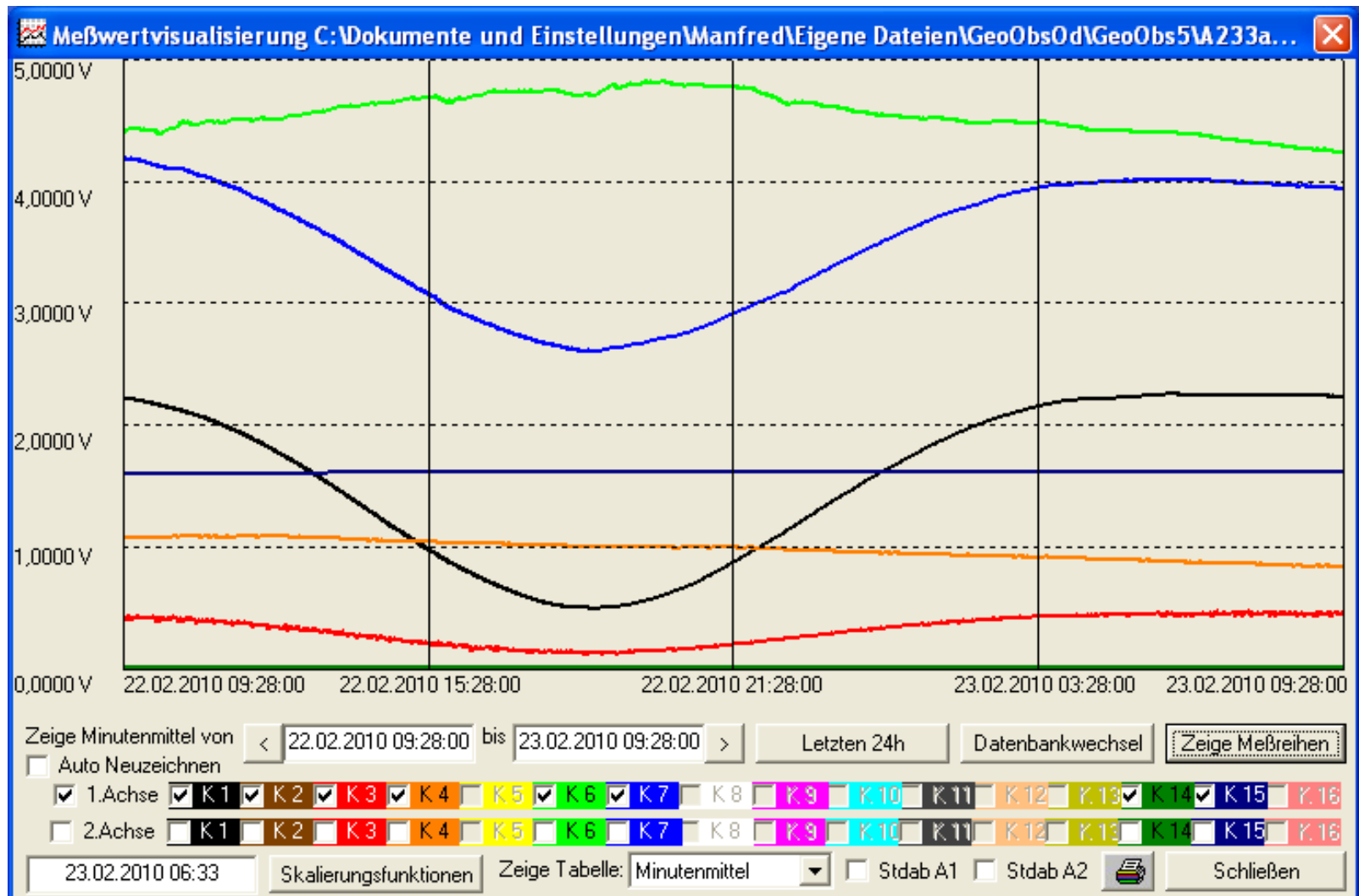


For inter-comparison parallel record of the signals of two gravimeters, sampling rate 1sec.



Zooming option for any time interval; here one hour, maximum 12 hours for sampling rate 1sec.

The component *Data Visualisation*



The component data evaluation/analysis



Sprungkorrektur

Wählen Sie den Kanal für die Sprungkorrektur. Bei einem zu berücksichtigenden Einlaufeffekt geben Sie bitte zusätzlich dessen Länge in Minuten und einen Polynomgrad zur Berechnung für die ausgleichende Funktion ein.

Wählen Sie den Kanal:

Zeitpunkt des Sprungs: Visu.

Soll die Sprungkorrektur einen Einlaufeffekt berücksichtigen?

☒ ohne Einlaufeffekt
☐ mit Einlaufeffekt

Polynomgrad für die Unterdrückung des Einlaufeffektes und die Berechnung der Sprunghöhe.

☐ linear
☒ quadratisch
☐ kubisch
☐ kubisch+quadratisch

Testen des Polynom

The correction of steps
without or with selectable time gap

Registrierlücken füllen

Füllen von Registrierlücken

Wählen Sie den Kanal, sowie das Datum und die Uhrzeit des ersten und des letzten richtigen Eintrags. Alle Datensätze zwischen den angegebenen Zeitpunkten (excl. dieser) werden interpoliert. Die weiteren Felder zeigen die Anzahl der fehlenden Datensätze und die Datensätze vor bzw. hinter der Lücke, die für den Polynomansatz zur Hilfe genommen werden.

Wählen Sie den Kanal: Kanal wählen Visu.

Beginn der Lücke:

Ende der Lücke:

☐ Lücke sythetisch füllen

Anz. fehlende Daten:

1. Datensatz f. Interpol.:

letzter Datensatz f. Inter.:

Wählen Sie den Polynomgrad für die Interpolation

☐ linear
☒ quadratisch
☐ kubisch
☐ kubisch+quadratisch

Testen des Polynom

The filling of short record gaps
(e.g. for earth tide analysis)

Anfelderung

Anfelderung

Wählen Sie die anzufeldernde Datenbank, den letzten Datensatz der aktuellen sowie den ersten anzufeldernden Datensatz der anzufeldernden Datenbank und die anzufeldernden Kanäle. Die Datensätze der zu wählenden Datenbank werden wahlweise sprungkorrigiert an die aktuelle Toolsdatenbank angefeldert.

ToolsDB: C:\Dokumente und Einstellungen\Ma

DB wählen:

letzter Datensatz: ..
 erster Datensatz: ..

Übertrag?	Sprung?	Übertrag?	Sprung?
Kanal 1 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Kanal 9 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Kanal 2 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Kanal 10 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Kanal 3 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Kanal 11 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Kanal 4 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Kanal 12 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Kanal 5 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Kanal 13 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Kanal 6 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Kanal 14 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Kanal 7 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Kanal 15 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Kanal 8 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Kanal 16 <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

Anfelderung starten Schließen

The affiliation of consecutive data sets

The calculation of hourly means

derived from minute means,
time interval: full hour minus
25 minutes until full hour plus
25 minutes; i.e. the means
are based on 50 values instead
of possible 60 values. Hence,
every hour one gets a time
window for performing metro-
logical measures without affecting
the hourly mean building.

Option of the interpolation
polynomial. For tidal analysis in
general the quadratic approach
is sufficient.

Free selection of channels for which
hourly means shall be calculated.
The individual mean buildings include
the calculation of the associated
standard errors.

Stundenmittel berechnen

Stundenmittelberechnung

Wählen Sie den Kanal, sowie den Polynomgrad für die Interpolation. Die interpolierten Stundenmittel beziehen sich jeweils auf 25 Minuten vor bis 25 Minuten nach jeder vollen Stunde. Die Mittelwerte werden in einer zusätzlichen Spalte in der Datenbanktabelle abgelegt.

Wählen Sie die Kanäle

- Kanal 1
- Kanal 2
- Kanal 3
- Kanal 4**
- Kanal 5
- Kanal 6
- Kanal 7**
- Kanal 8

Wählen Sie den Polynomgrad für die Berechnung der Stundenmittel.

- ☐ linear
- ☒ quadratisch
- ☐ kubisch
- ☐ kubisch+quadratisch

☐ Dateiauswahl

Export nach ETERNA 3.x

ETERNA-Export

Wählen Sie den Gezeitenkanal und die meteorologischen Zusatzkanäle, um die Daten der aktuellen Datenbank in das ETERNA 3.x - Format zu exportieren. Für die Beschreibung der ETERNA-internen Parameter s. Hilfedatei ETERNA34.hlp Abschnitt 17.3. Für den Export der Stundenmittel müssen diese zuvor mit Hilfe der Oberfläche "Stundenmittel" aus Tools generiert worden sein. Sie können außerdem den Zeitraum der zu exportierenden Daten über die Datumsfelder anpassen. Standardmäßig werden alle Datensätze exportiert.

Instrumentenname	Standard		<input type="checkbox"/> Dateiwahl	<input type="checkbox"/> ETERNA-Blöcke
DCAL	1,0000	10,0000	DTLAG	0,000
DSAPR	1,0000		NBIAS	0
Beginn des Exports	21.02.2010 11:35:0	...	Ende des Exports	23.02.2010 09:28:0 ...
Gezeitenkanal	Kanal 1 ▼		Gezeitenkanal-Offset	0,000
ETERNA Ini-Länge	30 Tage ▼		<input type="checkbox"/> Automatische ETERNA-Analyse nach Export	
meteorologische Zusatzkanäle (und zugehöriger Offset)				
<input type="checkbox"/> Gez	0,000	<input type="checkbox"/> K 5	0,000	<input type="checkbox"/> K 9
<input type="checkbox"/> K 2	0,000	<input type="checkbox"/> K 6	0,000	<input type="checkbox"/> K 10
<input type="checkbox"/> K 3	0,000	<input type="checkbox"/> K 7	0,000	<input type="checkbox"/> K 11
<input type="checkbox"/> K 4	0,000	<input type="checkbox"/> K 8	0,000	<input type="checkbox"/> K 12
<input type="checkbox"/> K 13	0,000	<input type="checkbox"/> K 14	0,000	<input type="checkbox"/> K 15
<input type="checkbox"/> K 16	0,000	<input type="checkbox"/> K 17	0,000	<input type="checkbox"/> K 18
Exportdateiname	C:\Dokumente und Einstellungen\Manfred\Eigene Dateien\GeoObs ...			
exportiere	<input checked="" type="radio"/> Minutenmittel <input type="radio"/> Stundenmittel		Export starten	
Exportformat	<input checked="" type="radio"/> ETERNA 3.x <input type="radio"/> TSoft		Schließen	

The tidal analysis with the ETERNA program system

STATION 0745 GeoObservatorium ODENDORF VERTIKALKOMPONENTE
 50 38 53 N 06 52 22 E H 172 M
 ASKANIA GRAVIMETER GS25 Nr.233
 INSTRUMENTELLE SIGNALVERZÖGERUNG 16,7 SEC

Adjusted tidal parameters :

Number of recorded days in total : 3295.21

from [cpd]	to [cpd]	wave [nm/s**2]	ampl.	ampl.fac.	stdv.	ph. lead [deg]	stdv. [deg]
0.501370	0.911390	Q1	66.8868	1.14652	0.00080	-0.2821	0.0401
0.911391	0.947991	O1	350.2290	1.14941	0.00016	0.0903	0.0078
0.947992	0.981854	M1	27.6119	1.15224	0.00174	0.3561	0.0865
0.981855	0.998631	P1	163.2344	1.15134	0.00037	0.1599	0.0184
0.998632	1.001369	S1	5.4416	1.62346	0.02265	5.1833	0.8032
1.001370	1.023622	K1	486.9308	1.13628	0.00011	0.2433	0.0058
1.023623	1.035379	TET1	5.3477	1.16704	0.01043	-1.0190	0.5122
1.035380	1.057485	J1	27.6897	1.15552	0.00202	0.3719	0.1001
1.057486	1.071833	SO1	4.5682	1.14925	0.01208	0.2433	0.6020
1.071834	1.470243	OO1	15.1998	1.15934	0.00274	0.1021	0.1355
1.470244	1.880264	2N2	10.6626	1.15414	0.00342	3.4141	0.1698
1.880265	1.914128	N2	68.0002	1.17544	0.00070	2.9170	0.0342
1.914129	1.950419	M2	359.1332	1.18856	0.00013	2.2422	0.0065
1.950420	1.984282	L2	10.0324	1.17468	0.00348	1.3128	0.1700
1.984283	2.002736	S2	167.4078	1.19084	0.00029	0.6711	0.0141
2.002737	2.451943	K2	45.5725	1.19259	0.00089	0.8739	0.0429
2.451944	3.381378	M3	3.9578	1.05056	0.00824	0.5763	0.4492
3.381379	4.347615	M4	0.0641	1.47371	0.65254	-83.2774	25.3695

Adjusted meteorological or hydrological parameters:

no.	regr.coeff.	stdv.	parameter	unit
1	-2.923905	0.26420	airpress	nm/s**2/hPa

Standard deviation of weight unit: 5.957 nm/s**2

Tools application 1: GeoObsOd - Results of tidal analysis

Program ANALYZE, version 3.30 960908

File: 039_052

STATION GeoDynLab/WULG

VERTIKALKOMPONENTE

49°39'53"N 06° 09'10"E (Salle P.M.) H 300m

Askania-Gravimeter A206

Signalverzögerung 0,0 sec

Adjusted tidal parameters :

Number of recorded days in total : 158.42

from [cpd]	to [cpd]	wave	ampl. [nm/s**2]	ampl.fac.	stdv.	ph. lead [deg]	stdv. [deg]
0.501370	0.911390	Q1	67.3331	1.14707	0.00290	-0.2393	0.1453
0.911391	0.947991	O1	351.8634	1.14768	0.00053	0.0338	0.0265
0.947992	0.981854	M1	27.7878	1.15244	0.00624	-0.1533	0.3099
0.981855	0.998631	P1	164.2261	1.15122	0.00109	0.1380	0.0549
0.998632	1.023622	S1K1	490.3804	1.13729	0.00037	0.1566	0.0187
1.023623	1.054746	J1	27.9100	1.15755	0.00733	-0.5609	0.3641
1.054747	1.470243	OO1	15.2471	1.15591	0.01509	-0.6152	0.7476
1.470244	1.880264	2N2	11.0436	1.14724	0.00762	3.9861	0.3811
1.880265	1.914128	N2	70.6771	1.17251	0.00143	3.4865	0.0699
1.914129	1.950419	M2	374.0192	1.18798	0.00024	2.3953	0.0116
1.950420	1.984282	L2	10.4365	1.17278	0.00523	1.4478	0.2555
1.984283	2.002738	S2	175.1030	1.19542	0.00056	0.8368	0.0273
2.002739	2.451943	K2	47.9126	1.20346	0.00221	1.1551	0.1051
2.451944	3.381378	M3	4.2826	1.06882	0.01044	-0.6980	0.5597
3.381379	4.347615	M4	0.0534	1.13095	0.62081	-123.3152	31.4532

Adjusted meteorological or hydrological parameters:

no.	regr.coeff.	stdv.	parameter	unit
1	+0.75998	0.054789	airpress	nm/s**2/hPa

Standard deviation of weight unit: 2.815 nm/s**2

Tools application 2: GeoDynLab/WULG – Results of tidal analysis

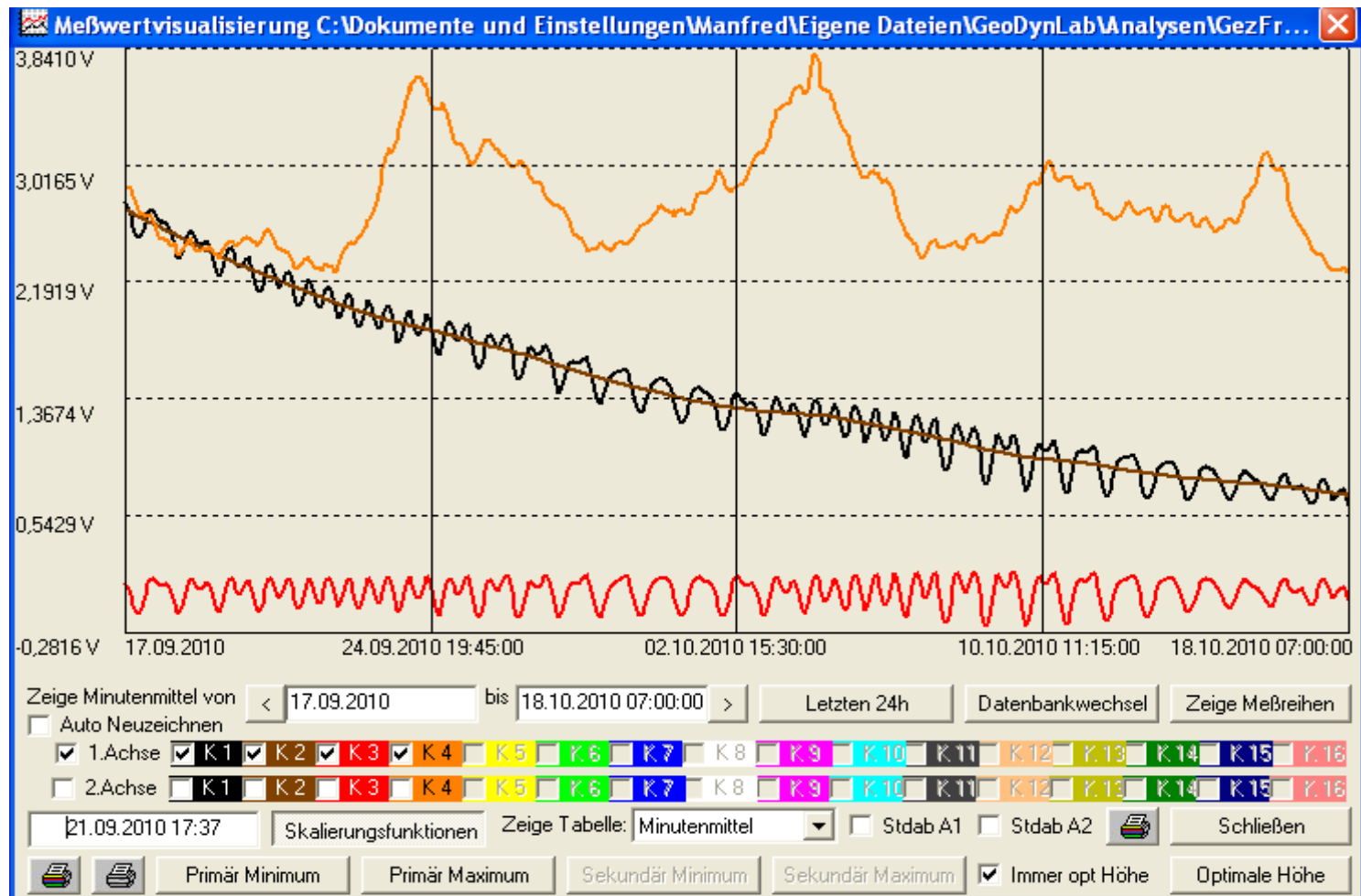
A plurality of technical and geo-scientific software had been developed for 32bit Operating Systems . This is the case too for the program systems Eterna and GeoDyn16k.

In the meantime a changeover from 32 to 64bit has started, with the consequence that computers with 32bit Operating Systems are no longer produced. The fatal result is that many of the presently applied programs can no longer be applied when employing a 64bit computer. The Eterna Program system and parts of the GeoDyn16k package (gravimetric tide prediction and analysis) are affected.

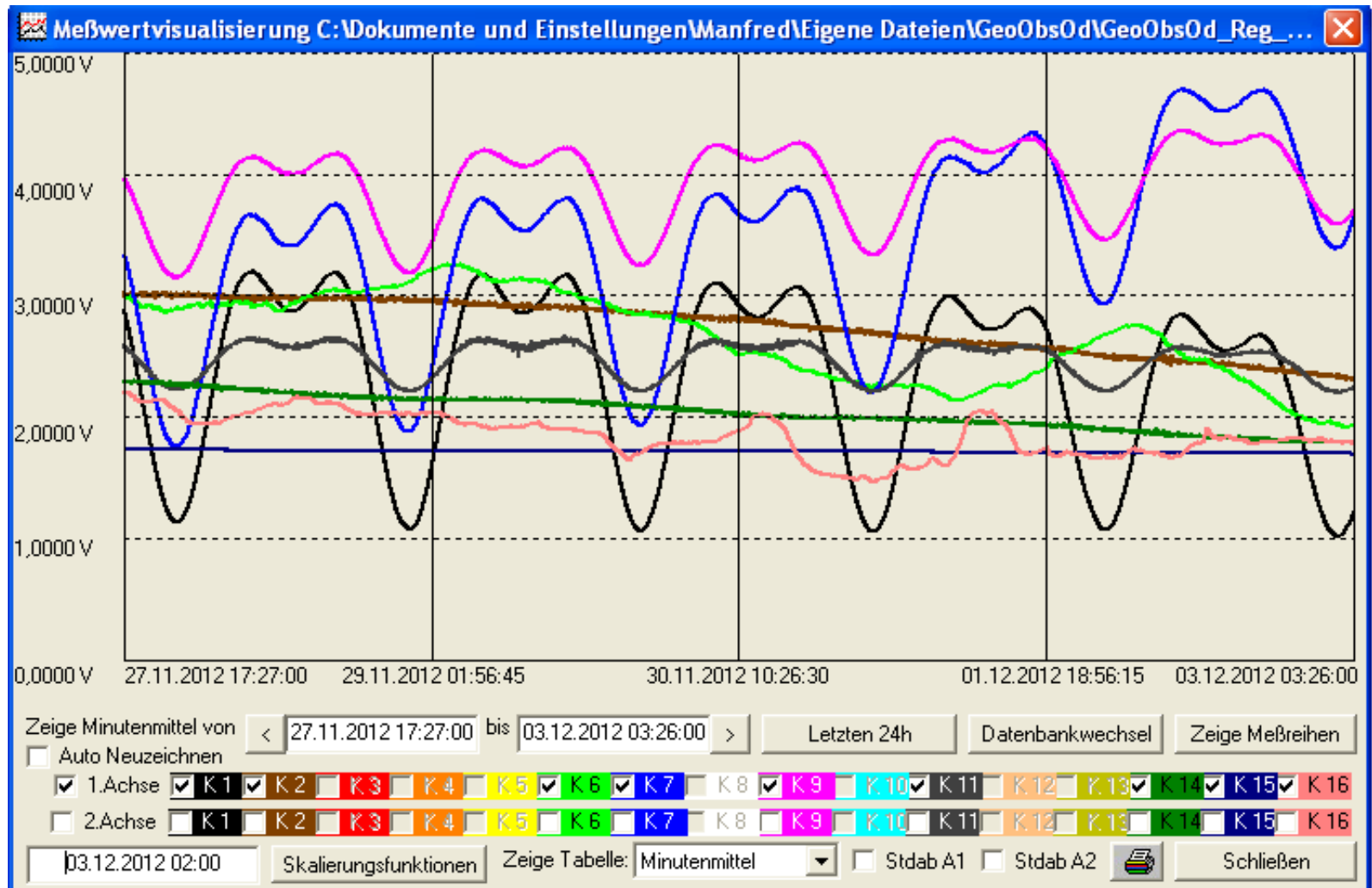
This particular problem has to be solved urgently (possibly by installing a virtual 32bit OS).

For users of Windows OS potentially an additional problem occurs when in 2014 the Extended Support for Windows XP will be stopped (2017 Vista, 2020 Windows 7).

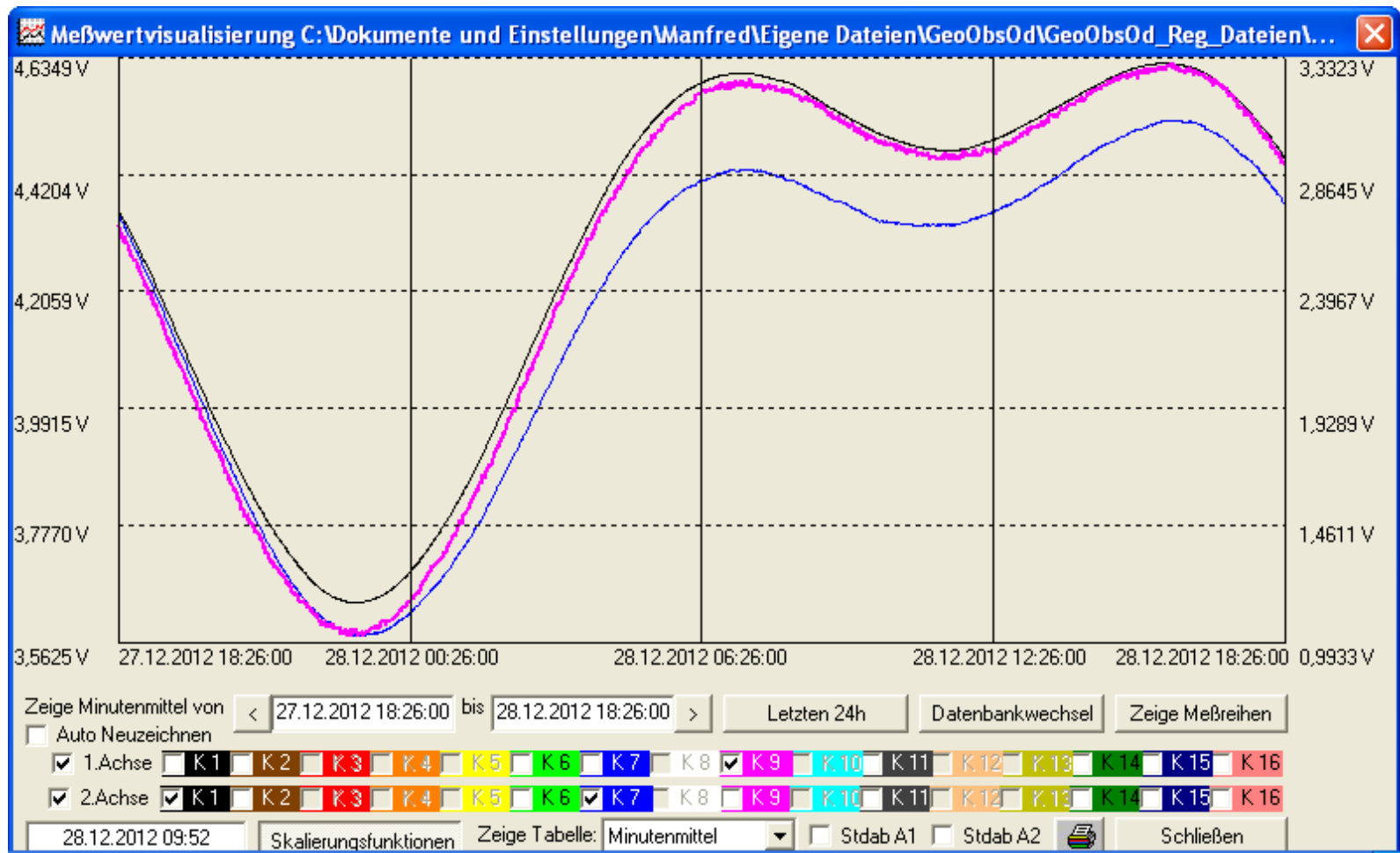
Some applications of the Program- Package *GeoDyn16k*



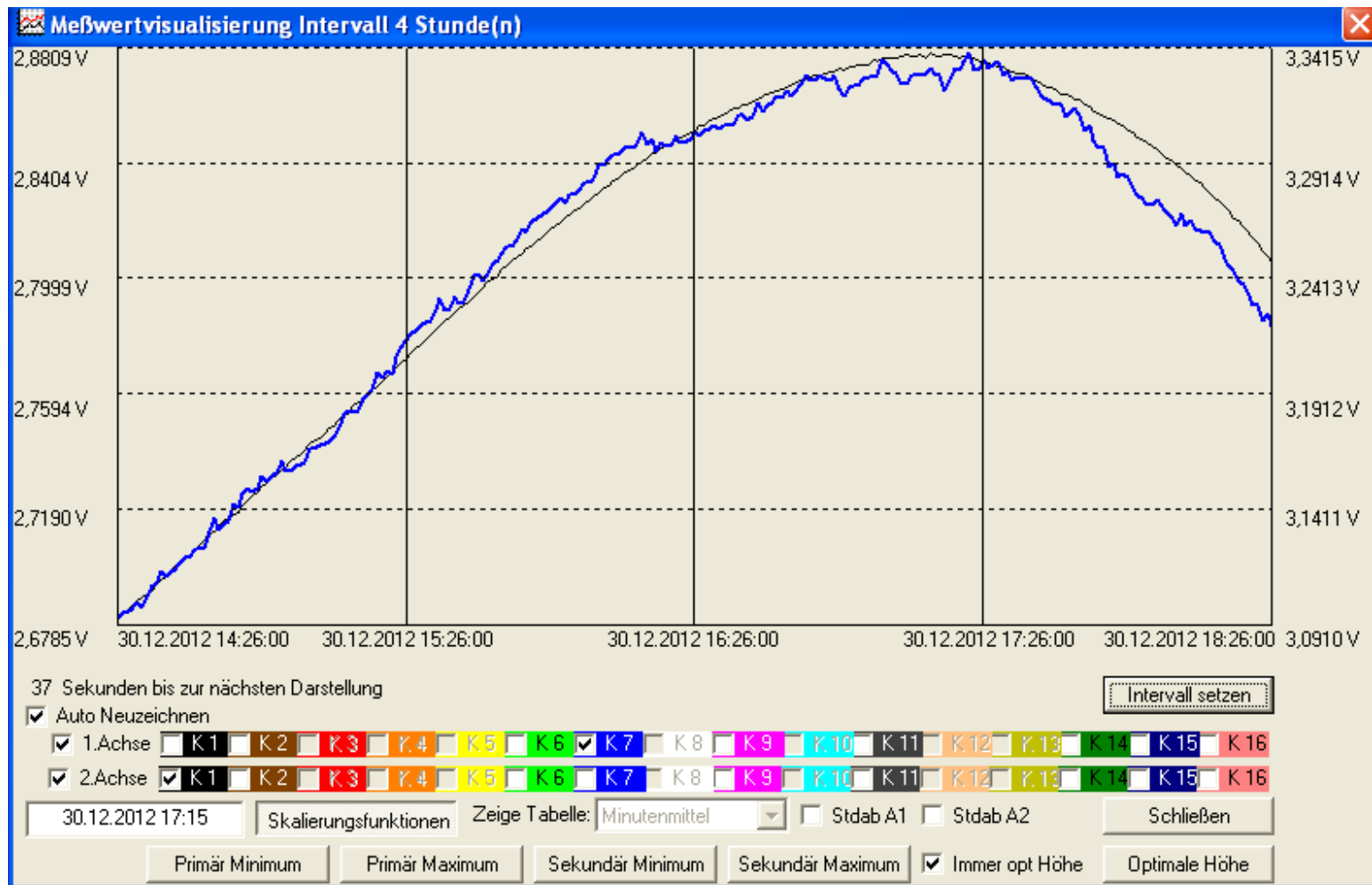
Tools application 3 : observed gravity signal, calculated instrumental drift, drift corrected signal, air pressure.
Investigation of the drift decay after the installation of a gravimeter in the GeoDynLab of the Walferdange Underground Observatory.



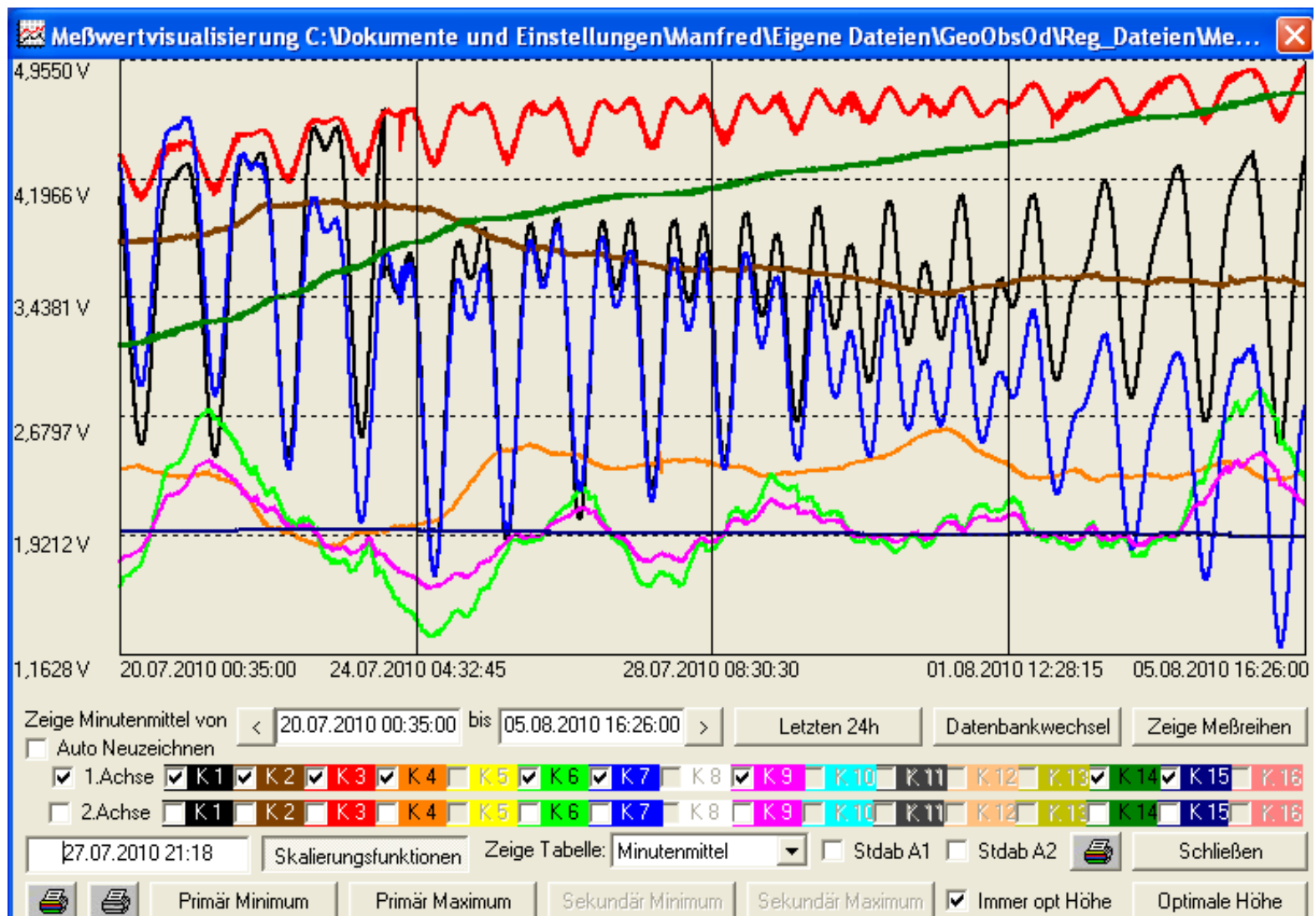
Sample 1a: GeoObservatorium Odendorf, parallel records of two tested LaCoste - Gravimeters with the metrological reference gravimeter A233, additionally records of air pressure, temperatures of chamber air and soil and outside temperature of the station.



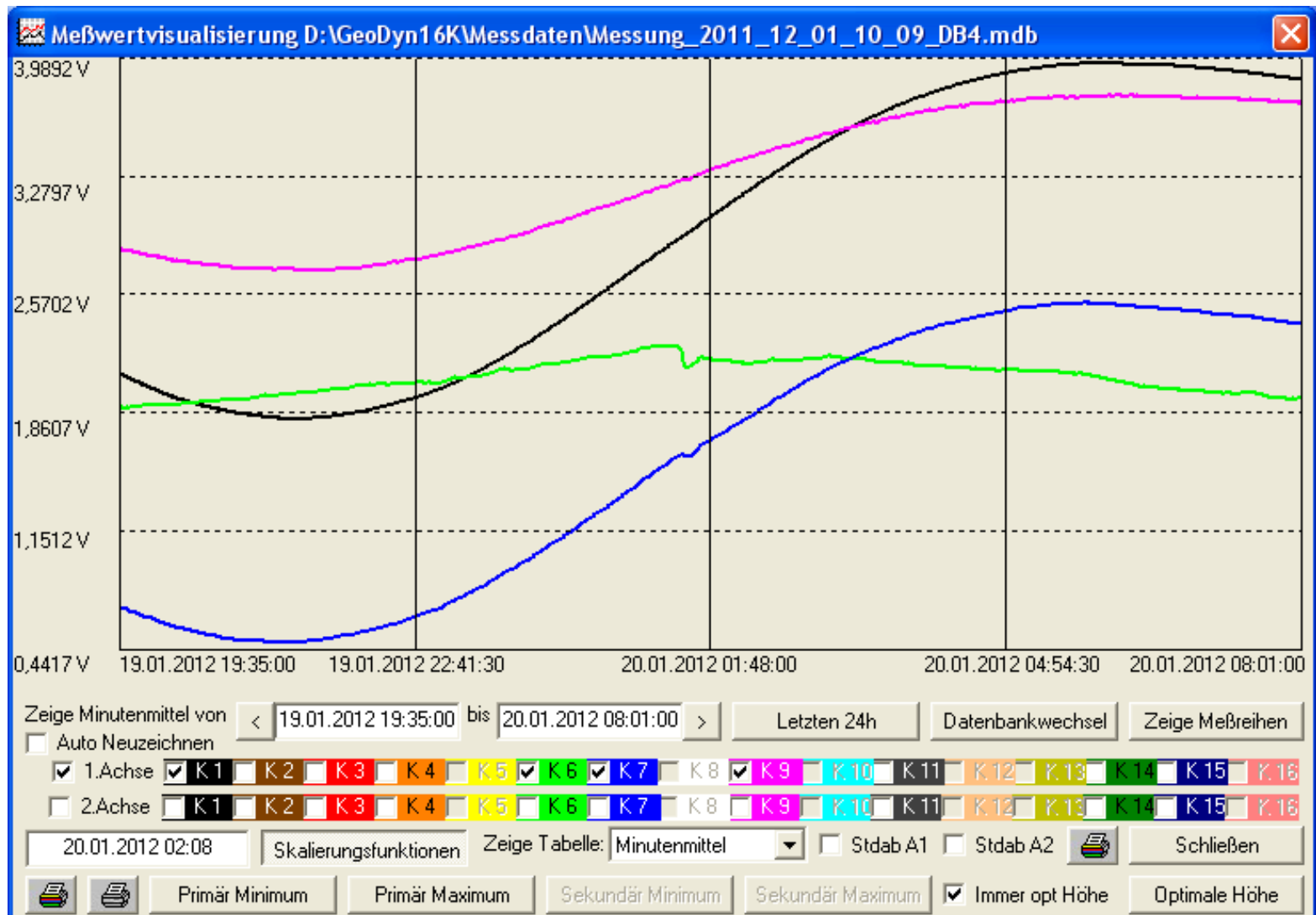
Sample 1b: detailed signal record of three Gravimeters during one day.



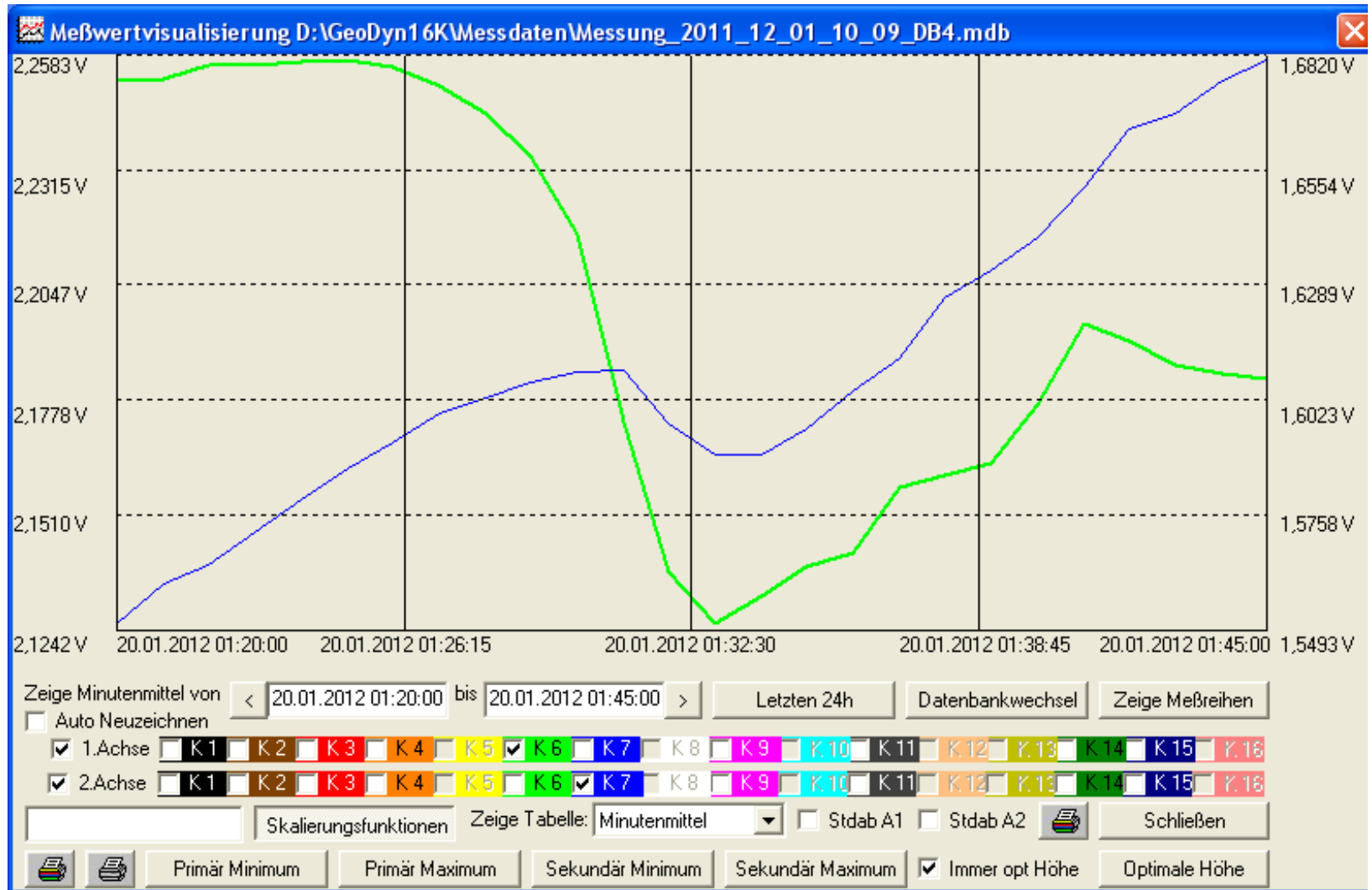
Sample 1c: the four hours record of a defective gravimeter in comparison with the reference gravimeter A233.



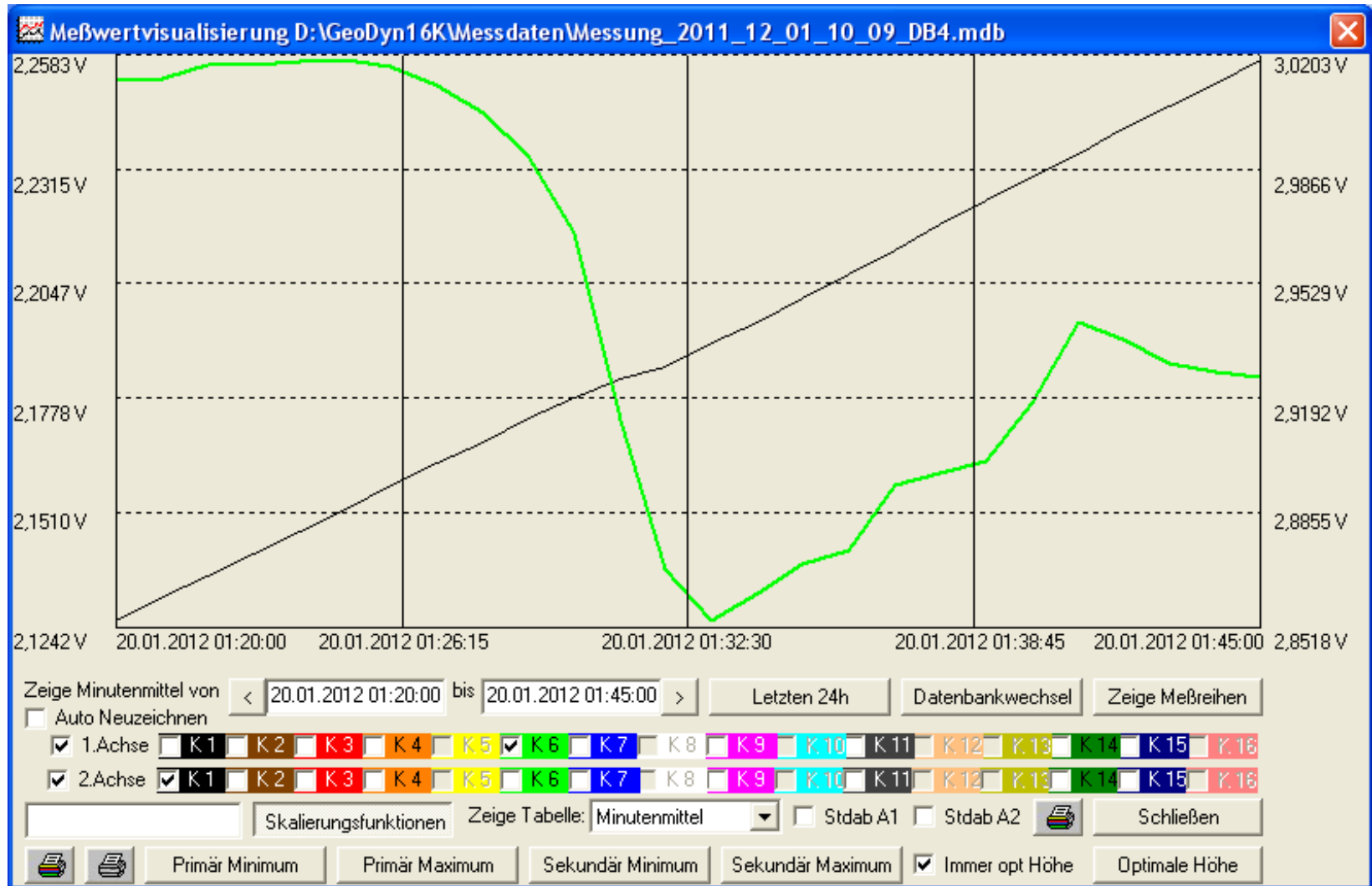
Sample 2: synopsis of the chronological run of nine different quantities .



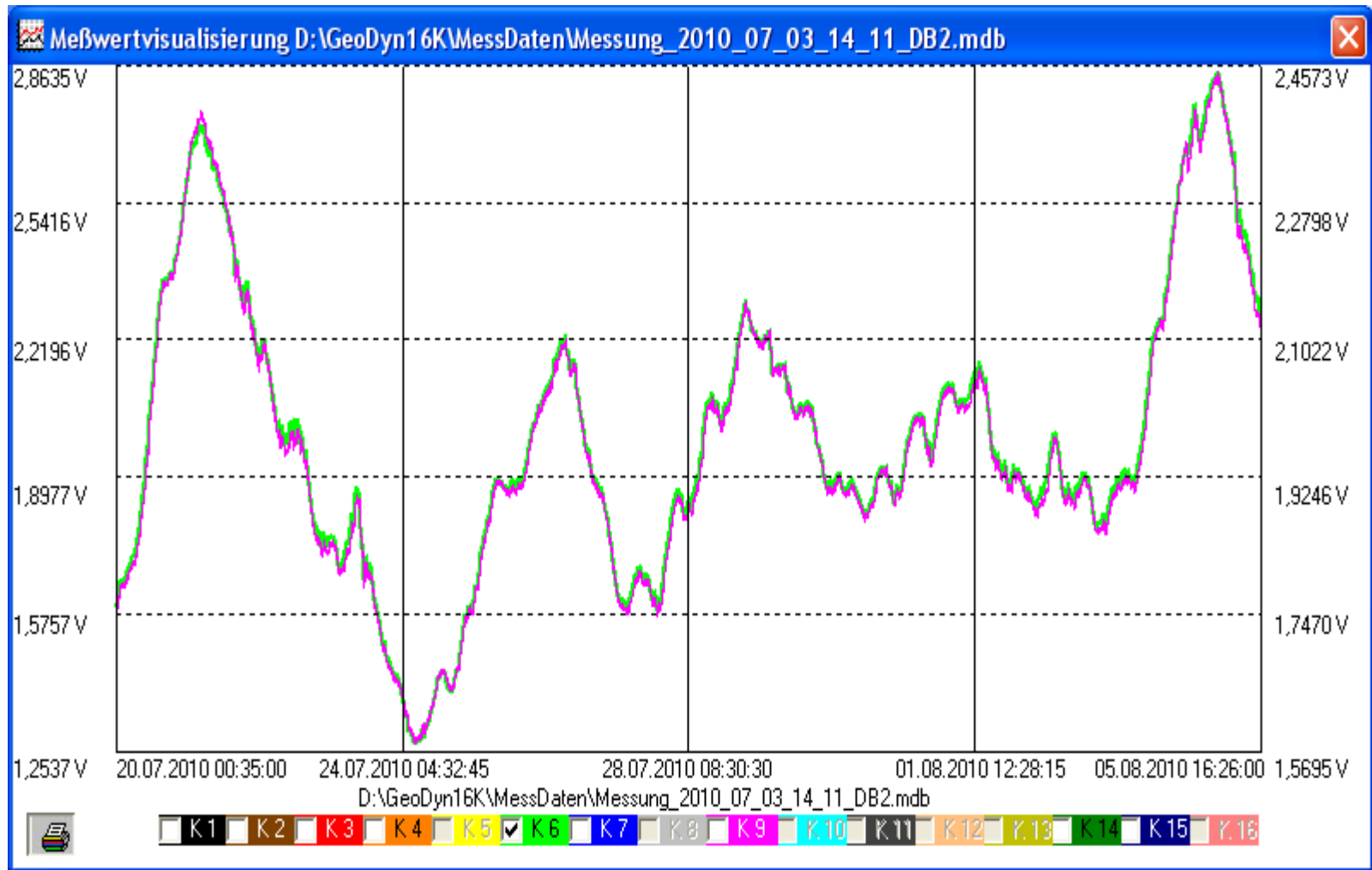
Sample 3a: Testing gravimeters for instrumental air pressure effects, green curve air pressure.



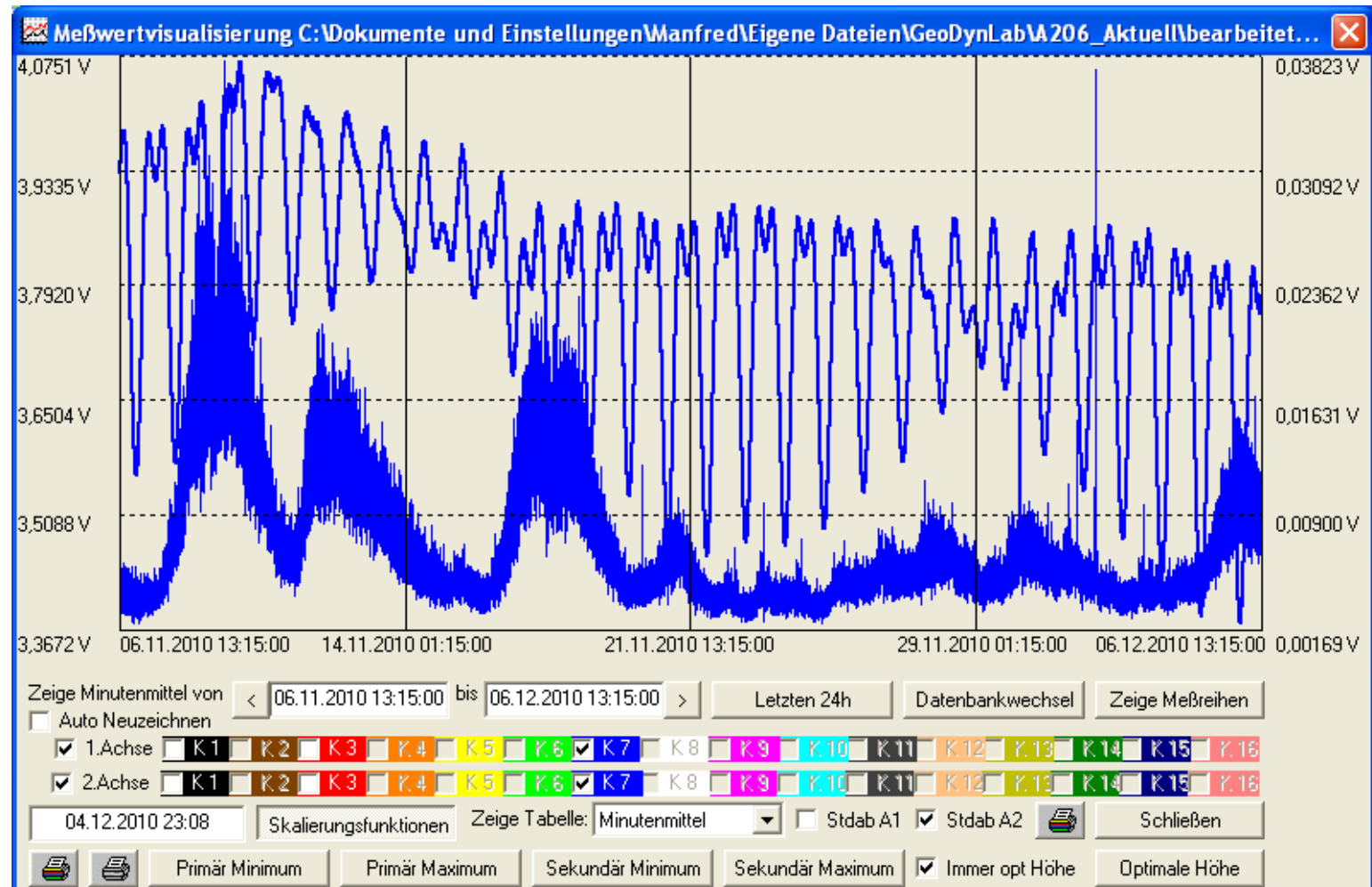
Sample 3b: Instrumental air pressure effect of a leaky gravimeter .



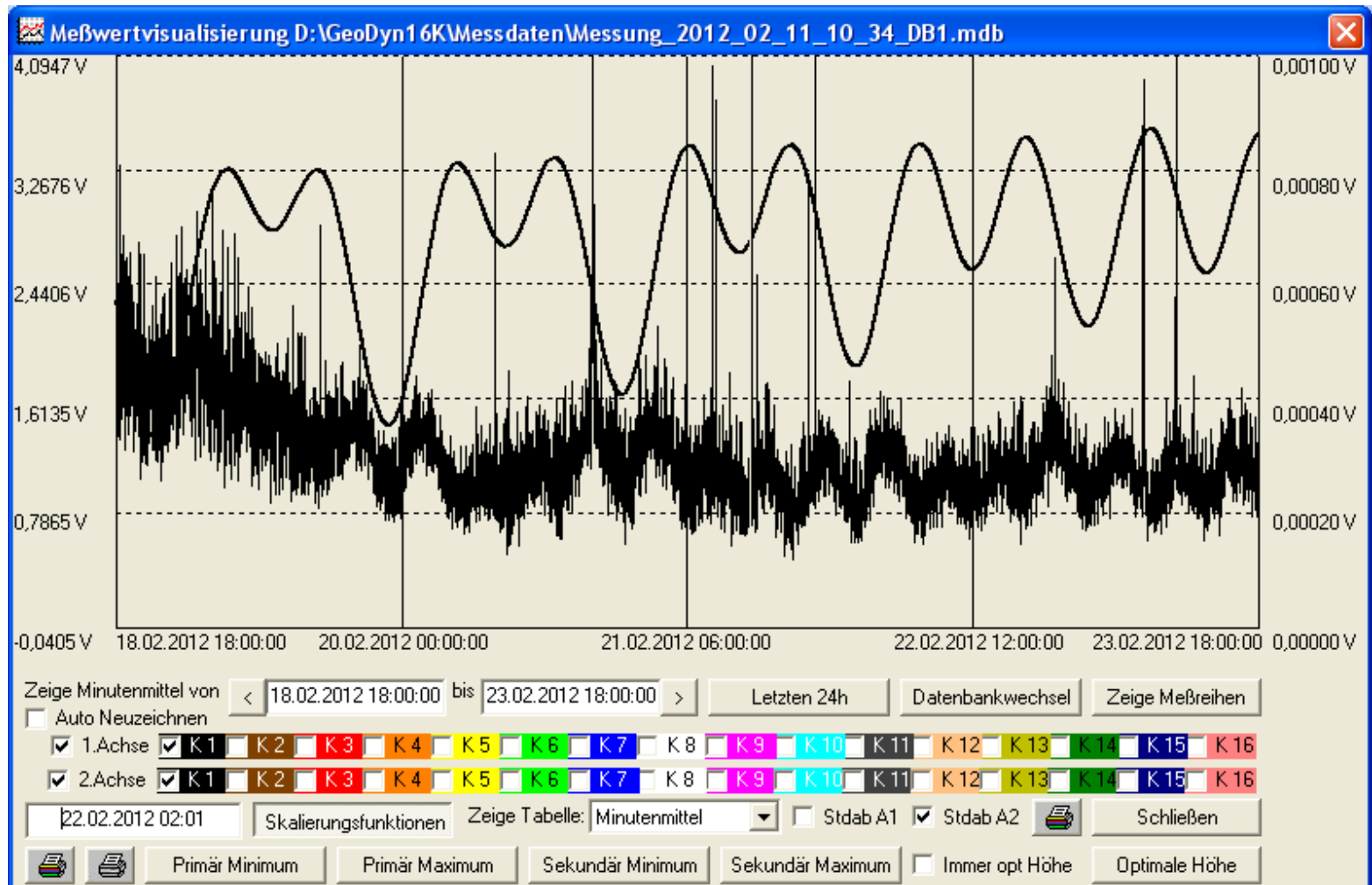
Sample 3c: The corresponding signal run of a hermetically sealed gravimeter.



Sample 4: GeoObsOd -Test and intercomparison of two high resolution barometers,
green curve: reference barometer 10mbar/Volt, right ordinate,
violet curve: barometer to be installed in the GeoDynLab/WULG.

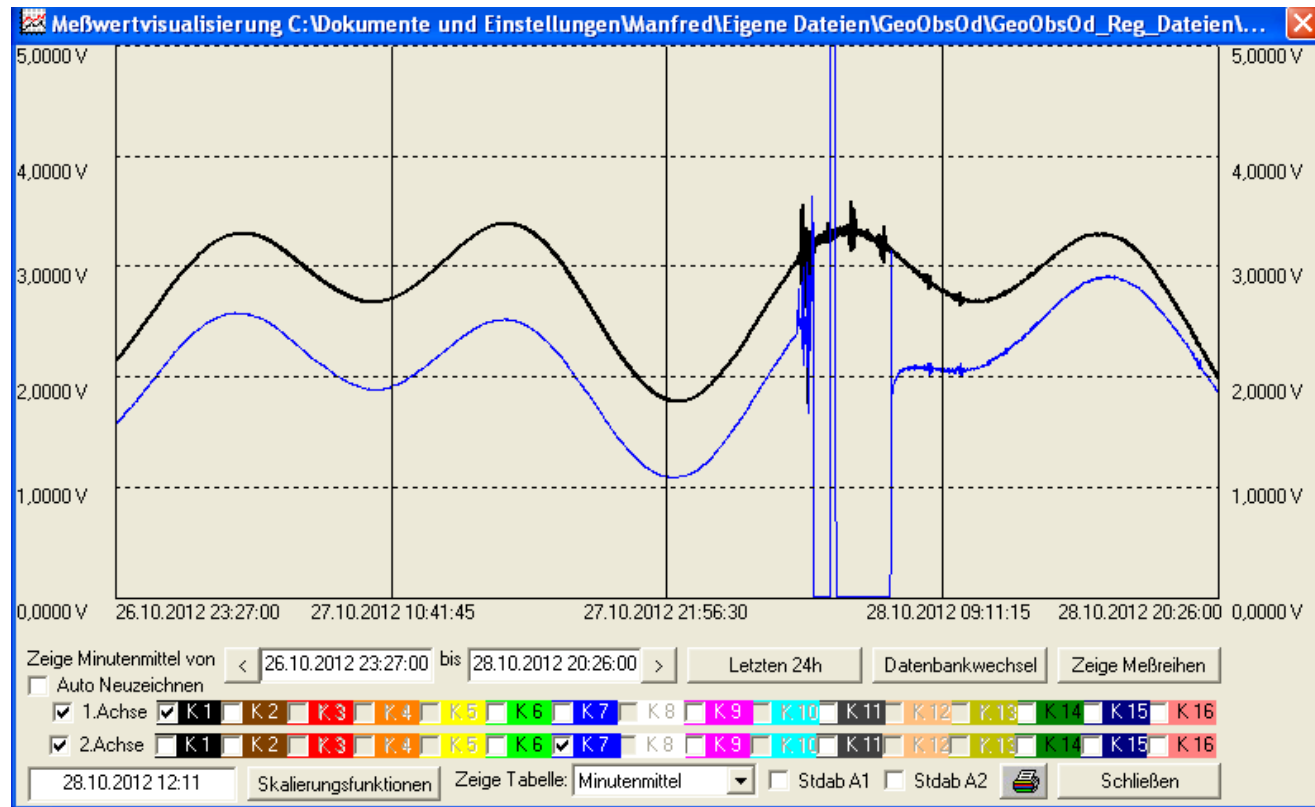


Sample 5: Synchronous display of a gravimeter signal and associated standard errors for a longer time span (here: one month, minute means).



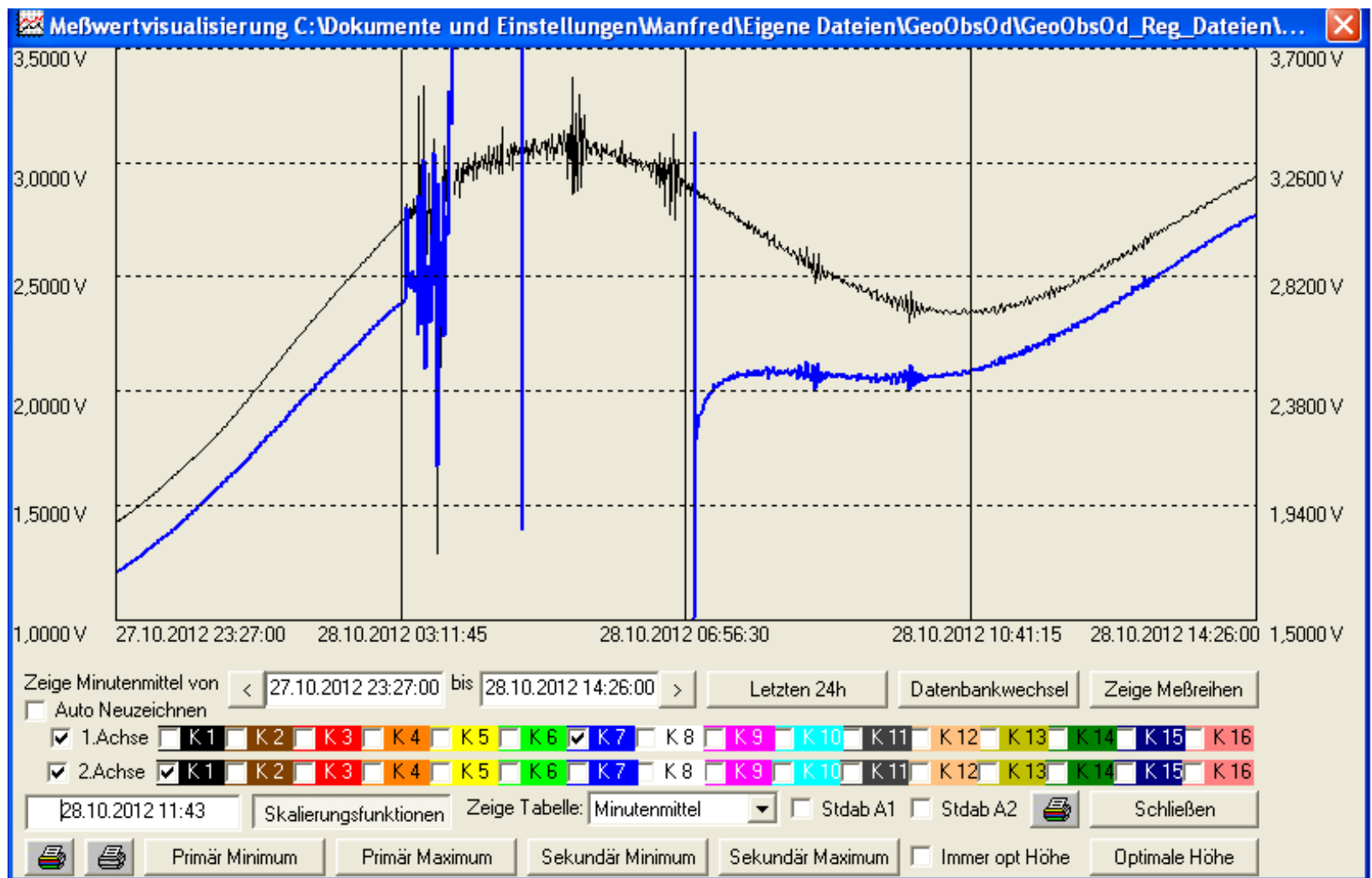
Sample 6: Determination of the true resolution of gravimetric data

The application of the formalism of arithmetic means within a one-minute-interval leads to visible errors when the basic noise level is sufficiently low and the changes of gravity per minute are sufficiently large (maximum about $0.9 \mu\text{Gal}/\text{minute}$); visible correlation of the chronological course of the calculated minute means with the course of the tidal signal.



Sample 7a: The effect of earth quake induced sensor oscillations: follow-up movement of the sensor of a feedback controlled LaCoste spring gravimeter after the release from sticking at a mechanical stop unit during about 3 hours.

Due to the reaction inertia of the feedback system , it can not compensate the short period earth quake induced sensor oscillations. Effect of elastic hysteresis. For comparison the corresponding signal sequence of the reference gravimeter A233 (no astatisation, no feedback, black curve).



Sample 7b: Detailed view of the effect mentioned before.