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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.

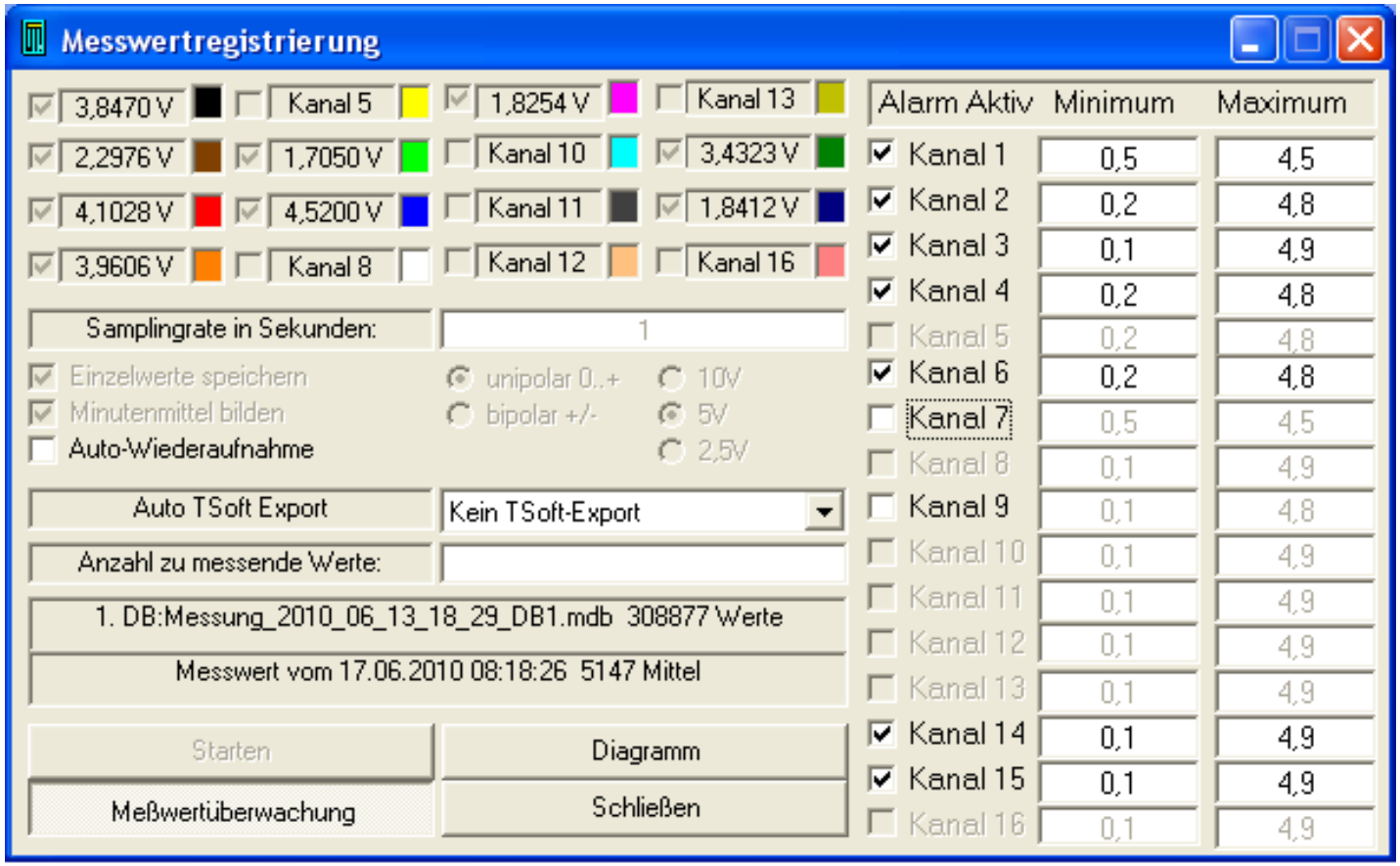
Within the research activities of the Geodynamical Observatory of the Bonn University (GeoObservatorium Odendorf) a corresponding program system was developed by Marc Eschmann, called *GeoDyn16k*. It was published in: *Marc Eschmann, Experimentelle und numerische Untersuchungen gravimetrischer Gezeitenparameter 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.

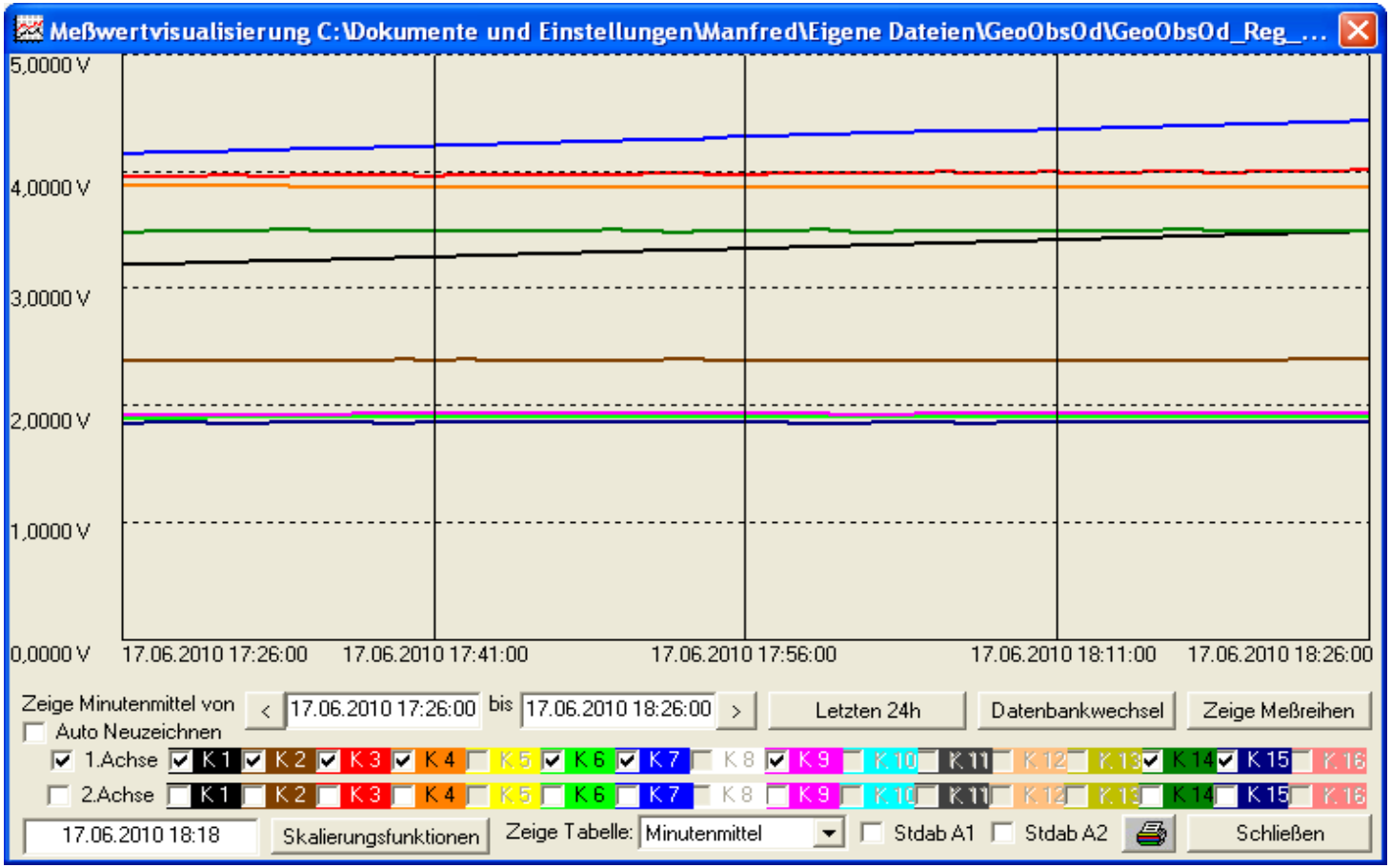
The main features of the components will be described and demonstrated. The performance of the program is illustrated by means of several relevant gravimetric examples.

The component *Data Acquisition*

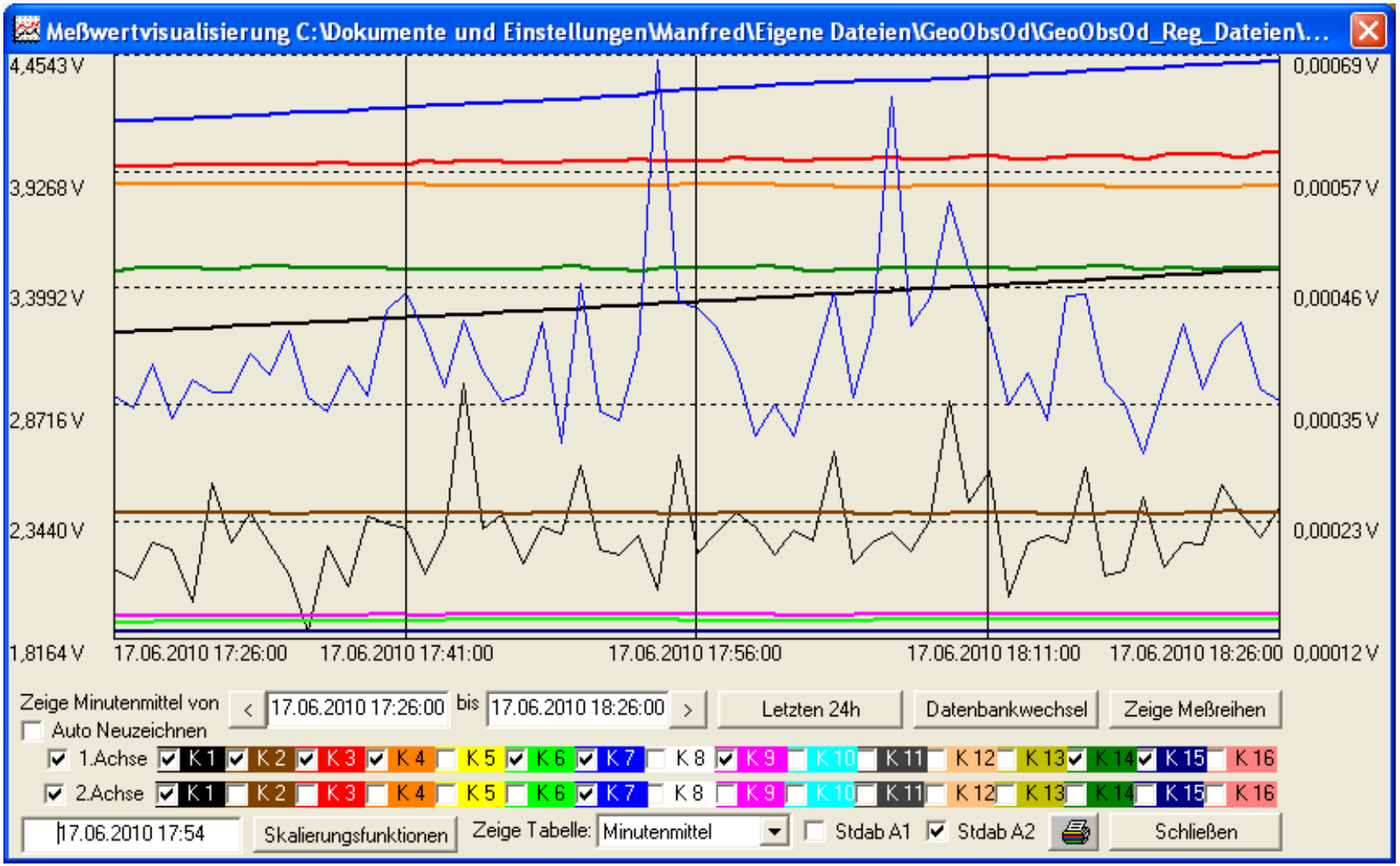


Sampling rate of signal digitalisation selectable, down to 0,001sec, standard 1sec. Option of setting a measurement interval (number of data to be measured); if no indication after 16 days (file length 907 MB) without gap automatically start of a new file for better handling of long observation series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

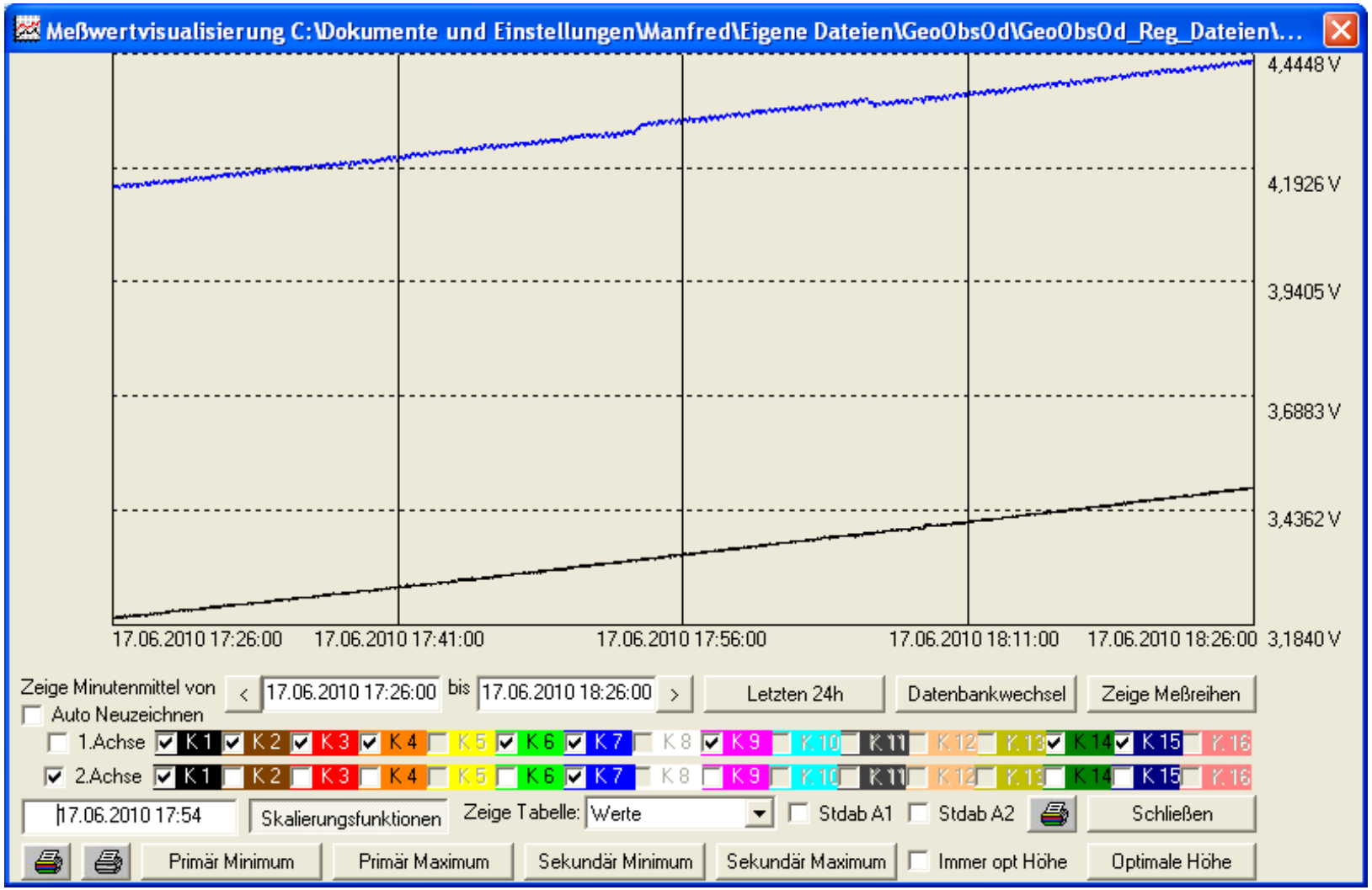
An acoustical alarm can for any channel optionally be activated when the measurement exceeds or falls below a tuned value.



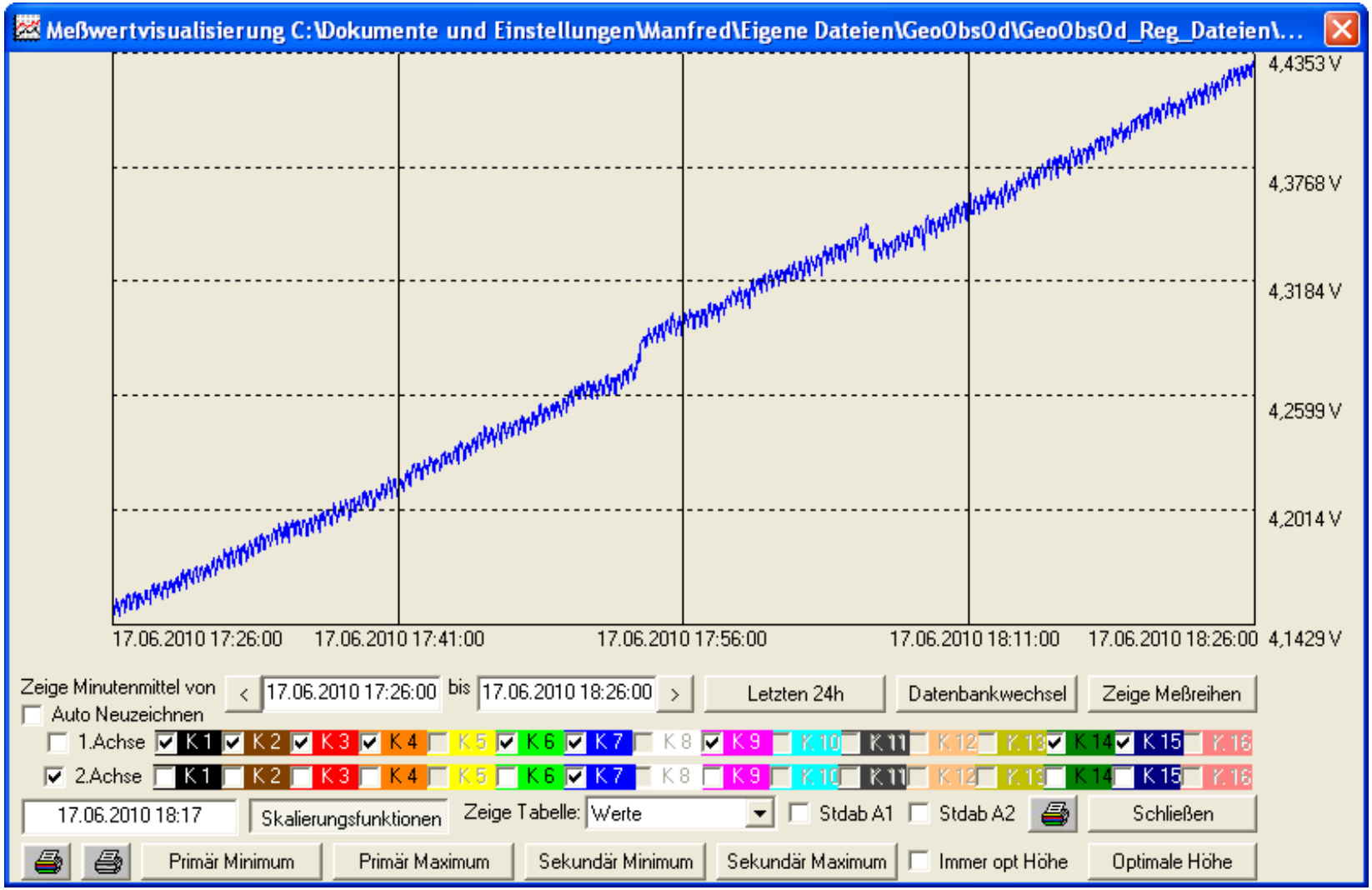
Current real time diagram, update every minute, display interval arbitrary (standard one hour), display option: current run *of single values* or *minute means* with associated standard errors (for intervals from full minute minus 30sec until full minute plus 29sec) to be displayed alternatively in a one-ordinate or two-ordinate diagram. The time corresponding to the position of the mouse curser 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).

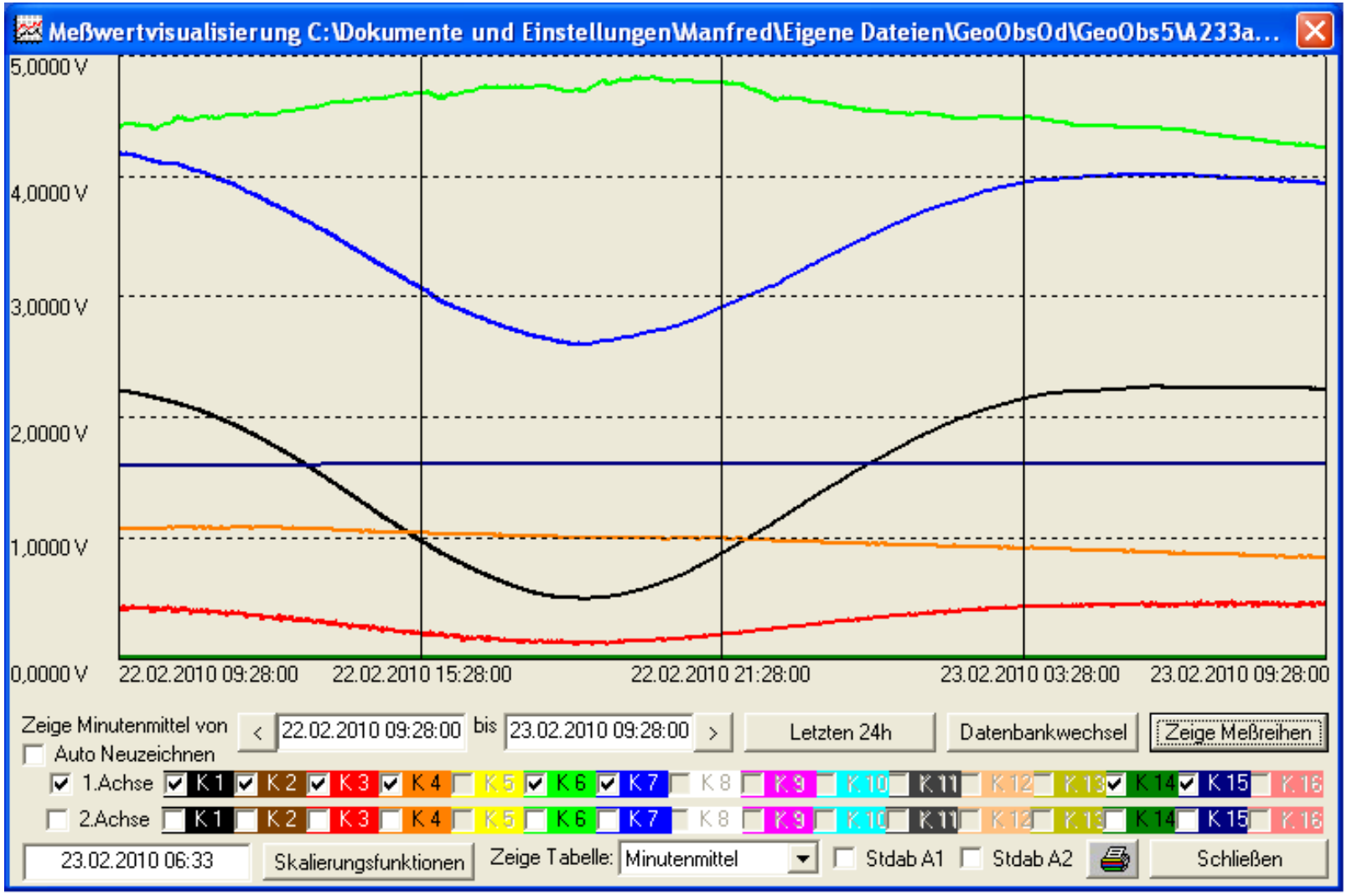


For inter-comparison parallel record of the signals of two gravimeters, sampling rate 1sec.

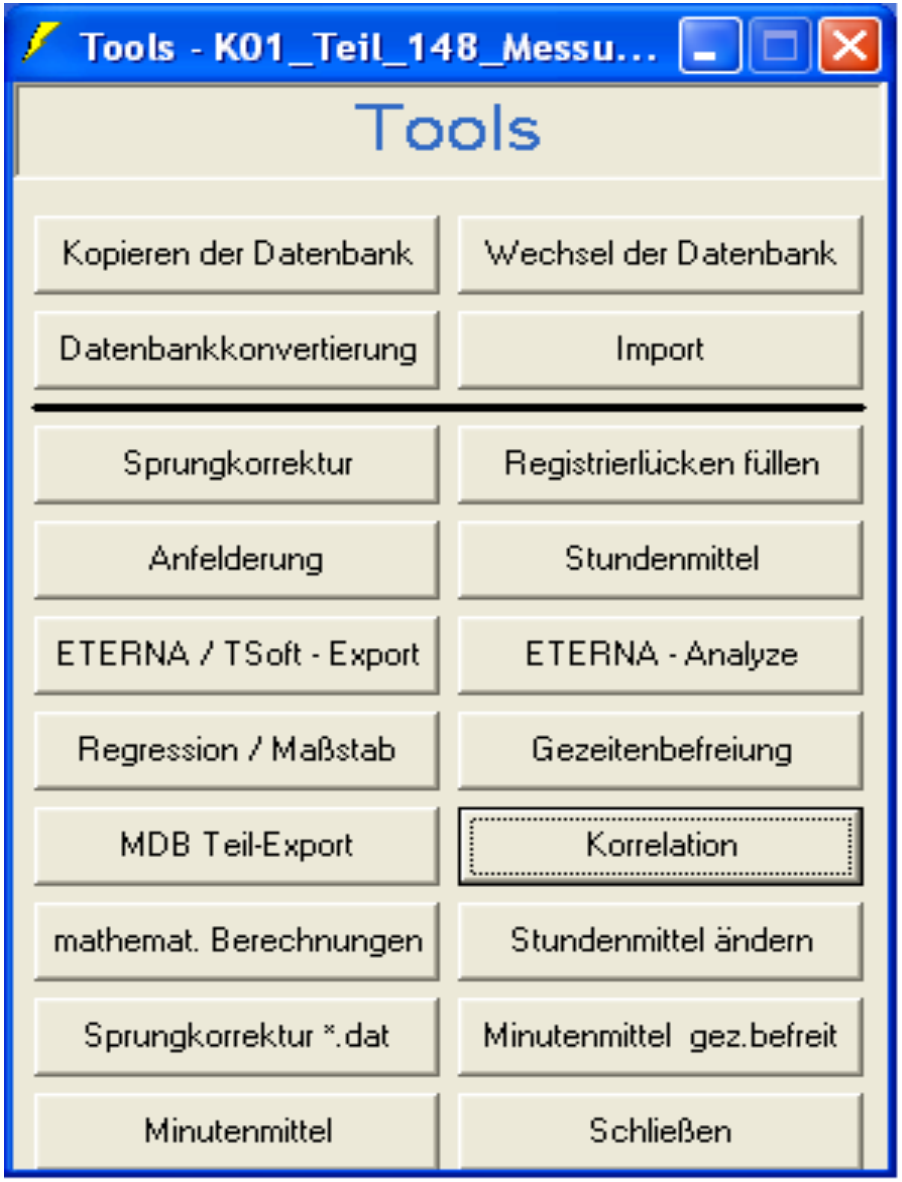


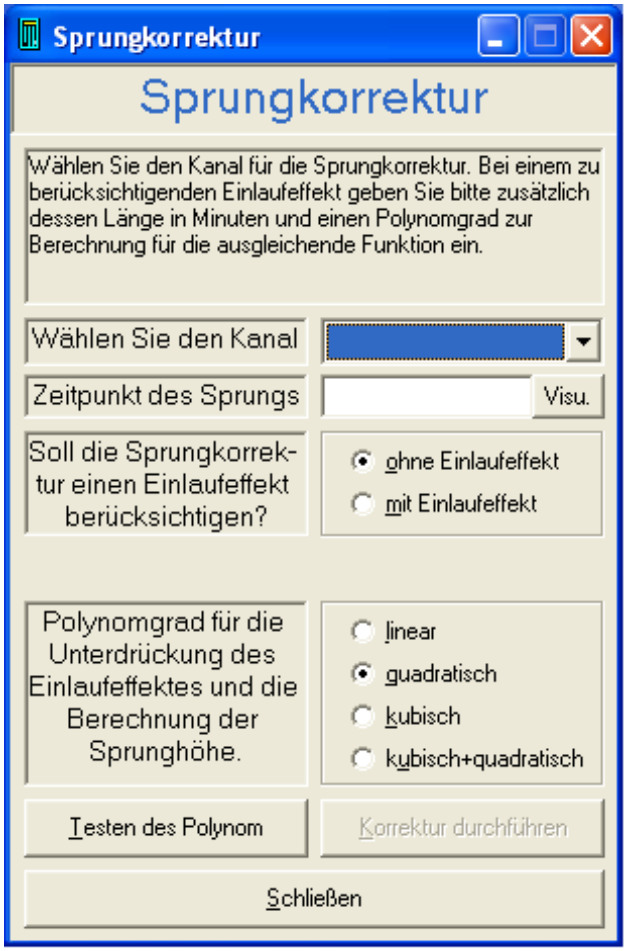
Zooming option for any time interval; here one hour, maximum 12 hours for sampling rate 1sec.

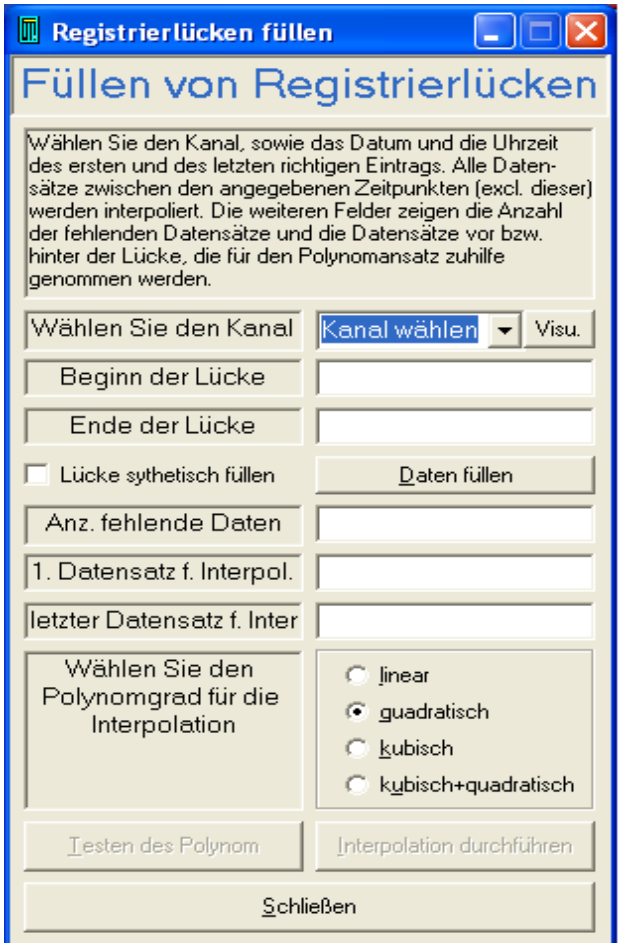
The component *Data Visualisation*



The component data evaluation/analysis

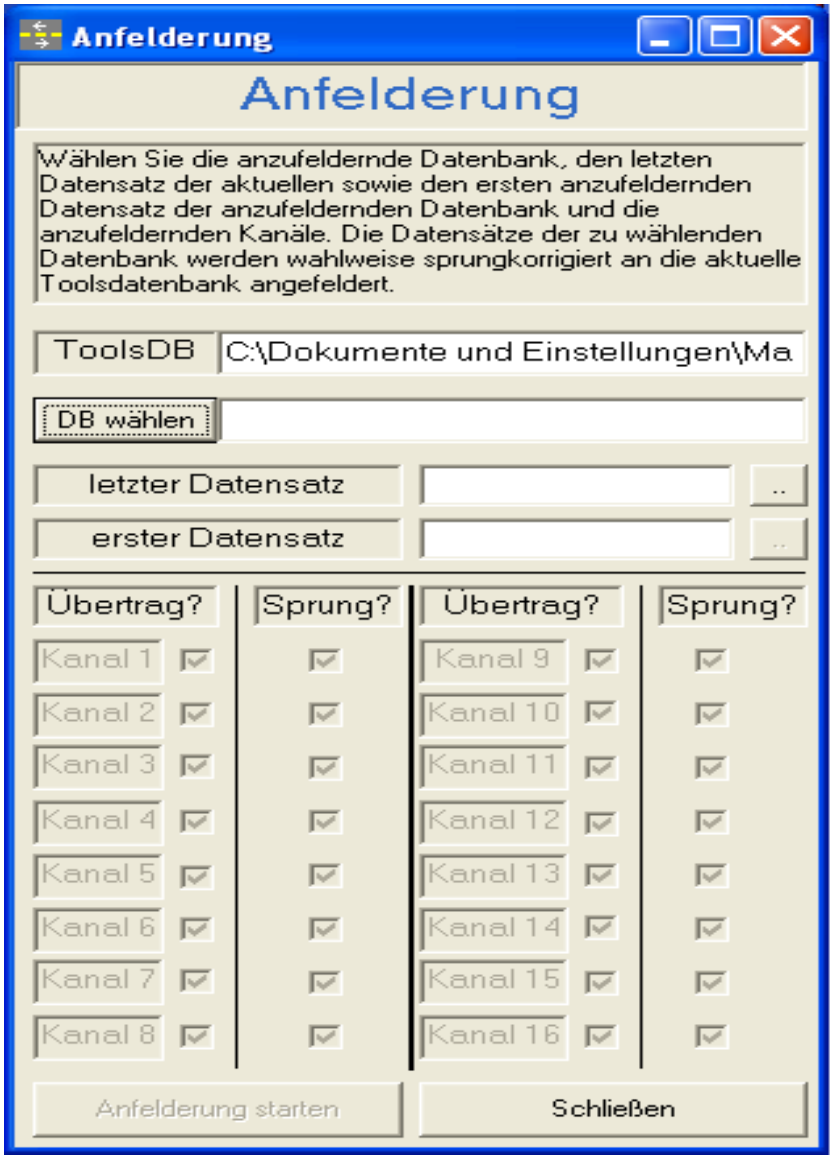






The correction of steps
without or with selectable time gap

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



The affiliation of consecutive data sets

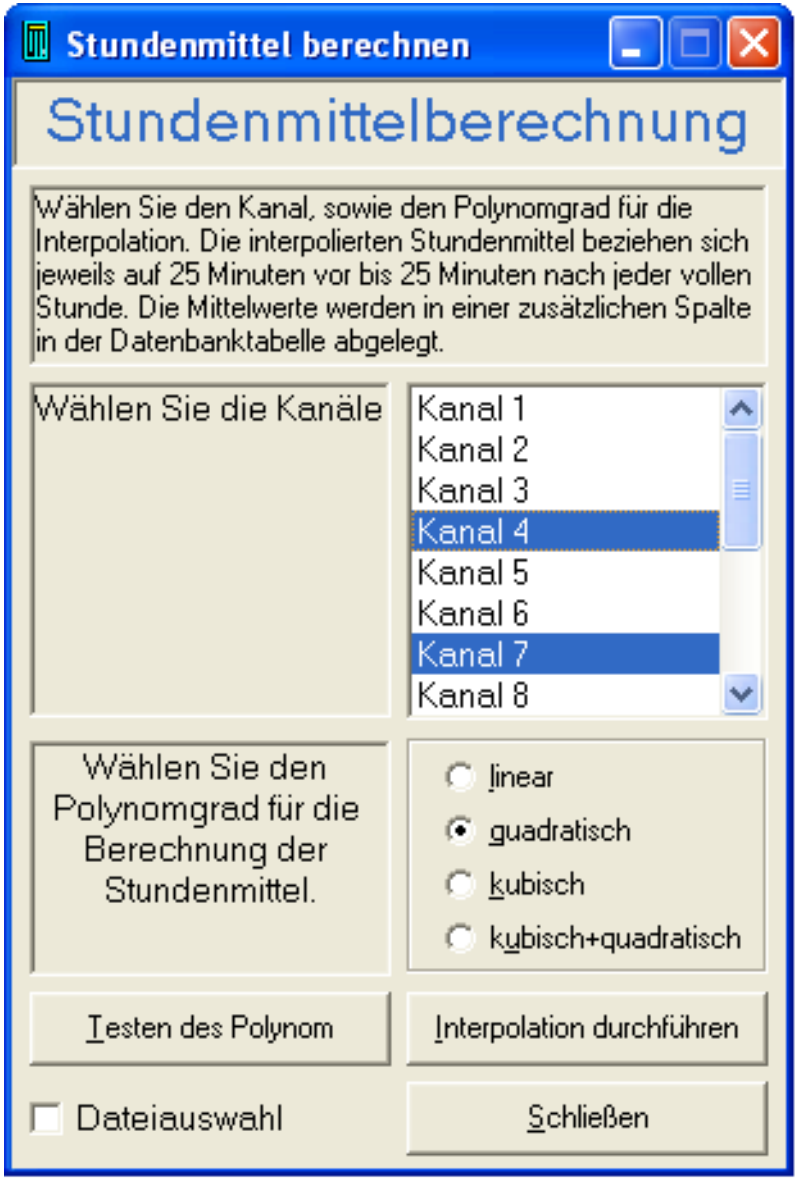
The calculation of hourly means

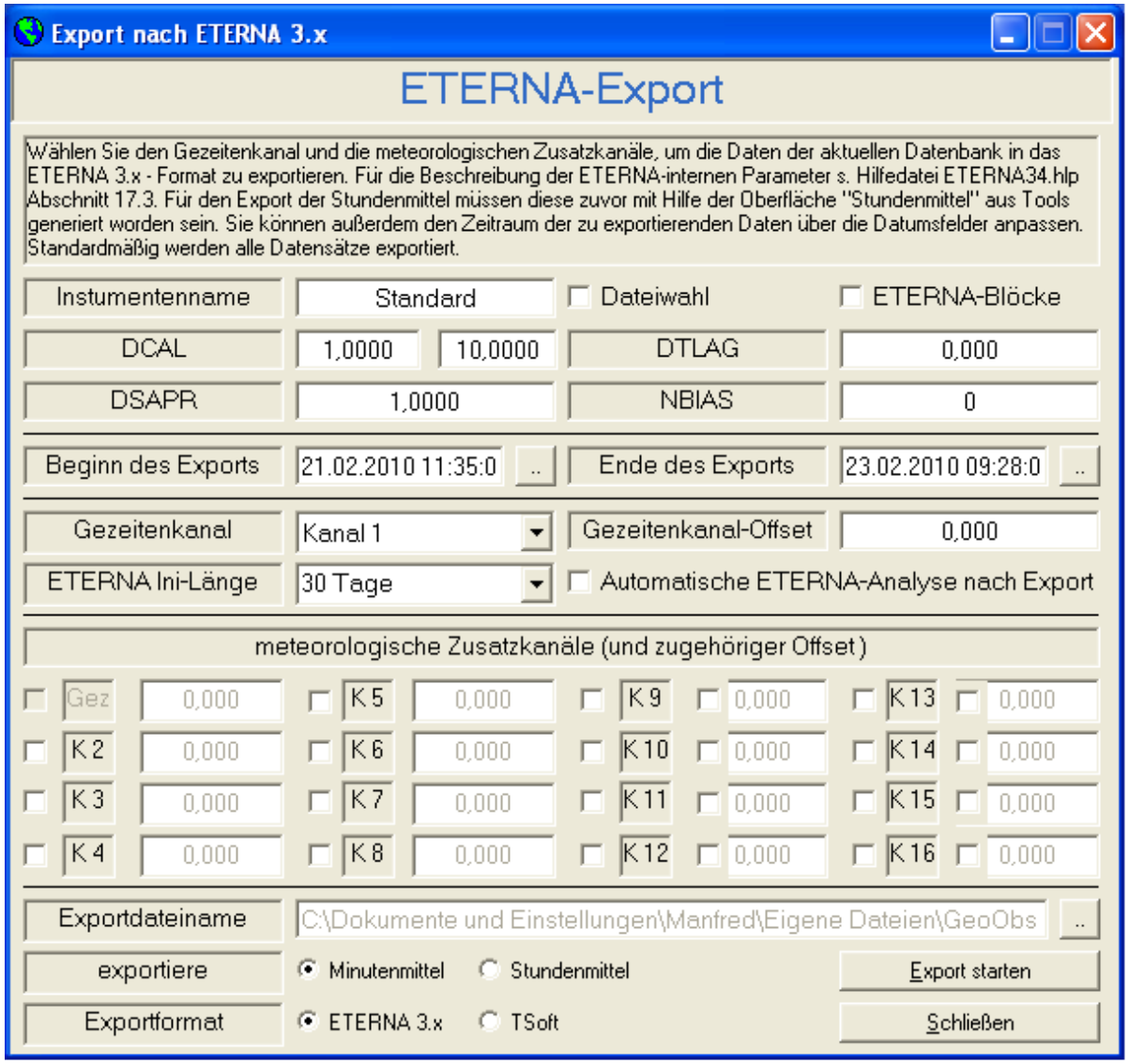
derived from minute means, time interval: full hour minus 25 minutes until full hour plus 25 minutes; i.e. the means are based on 50 values instead of possible 60 values. Hence, every hour one gets a time window for performing metro-logical measures without affecting the hourly mean building.

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.





The tidal analysis with the ETERNA program system

Program ANALYZE, version 3.30 960908 File: 8K_221

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	ampl. [nm/s**2]	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      to      wave    ampl. ampl.fac.    stdv. ph. lead    stdv.
      [cpd]     [cpd]     [nm/s**2 ]                        [deg]    [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

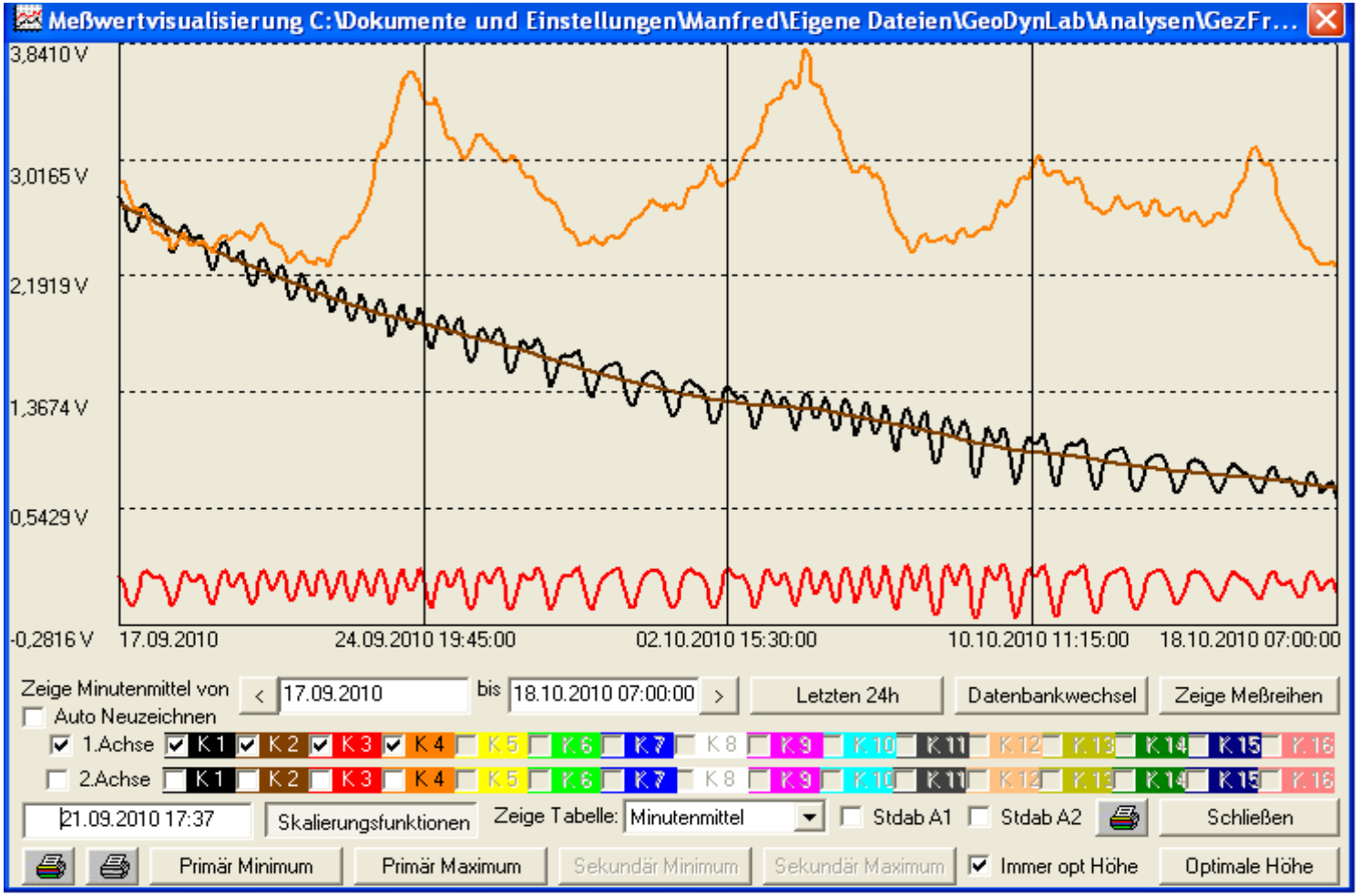
A plurality of technical and geo-scientific software had been developed for 32bit Operating Systems . This is the case too for the program systems Eterna and GeoDyn16k.

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.

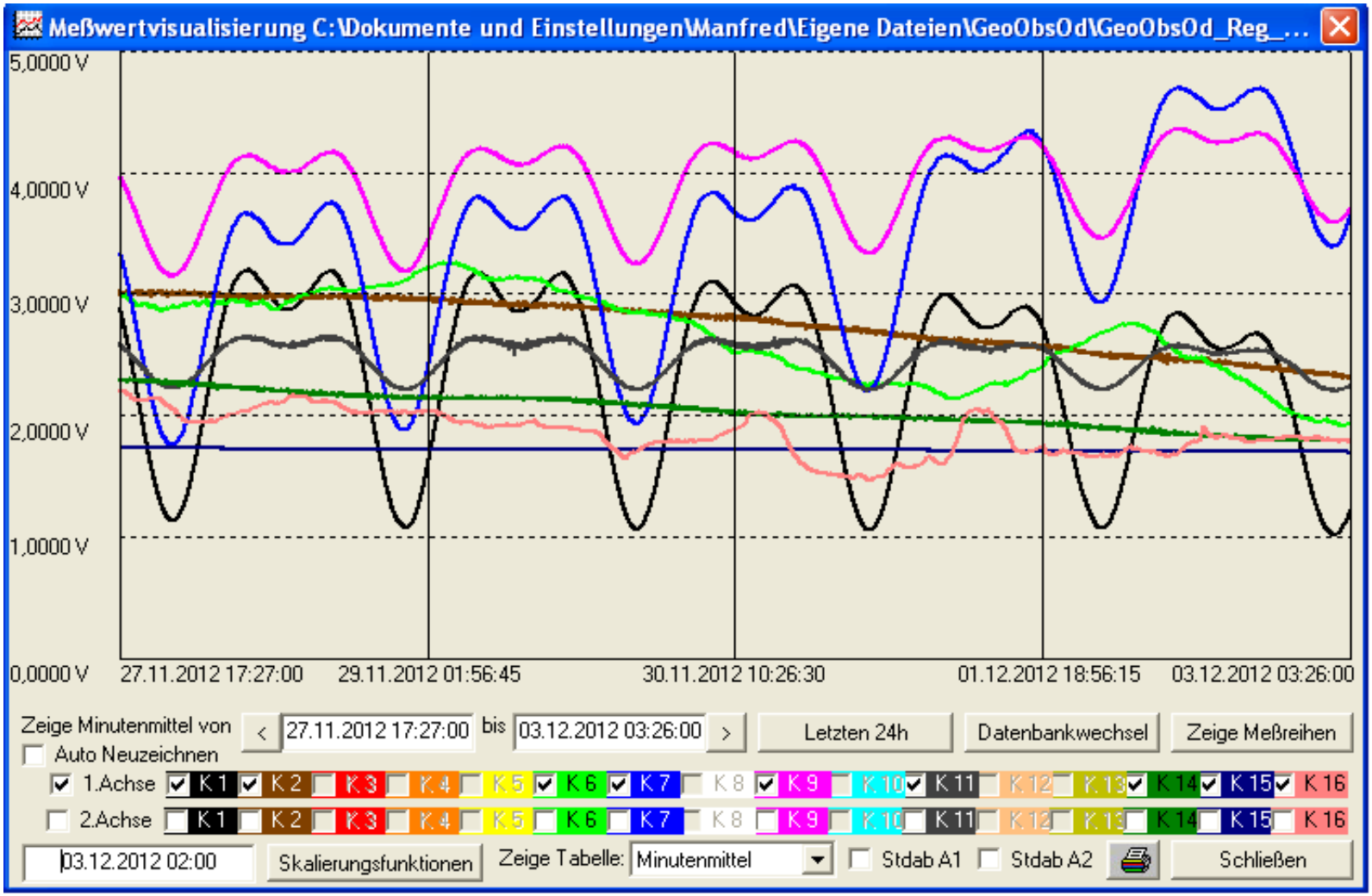
This particular problem has to be solved urgently (possibly by installing a virtual 32bit OS).

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).

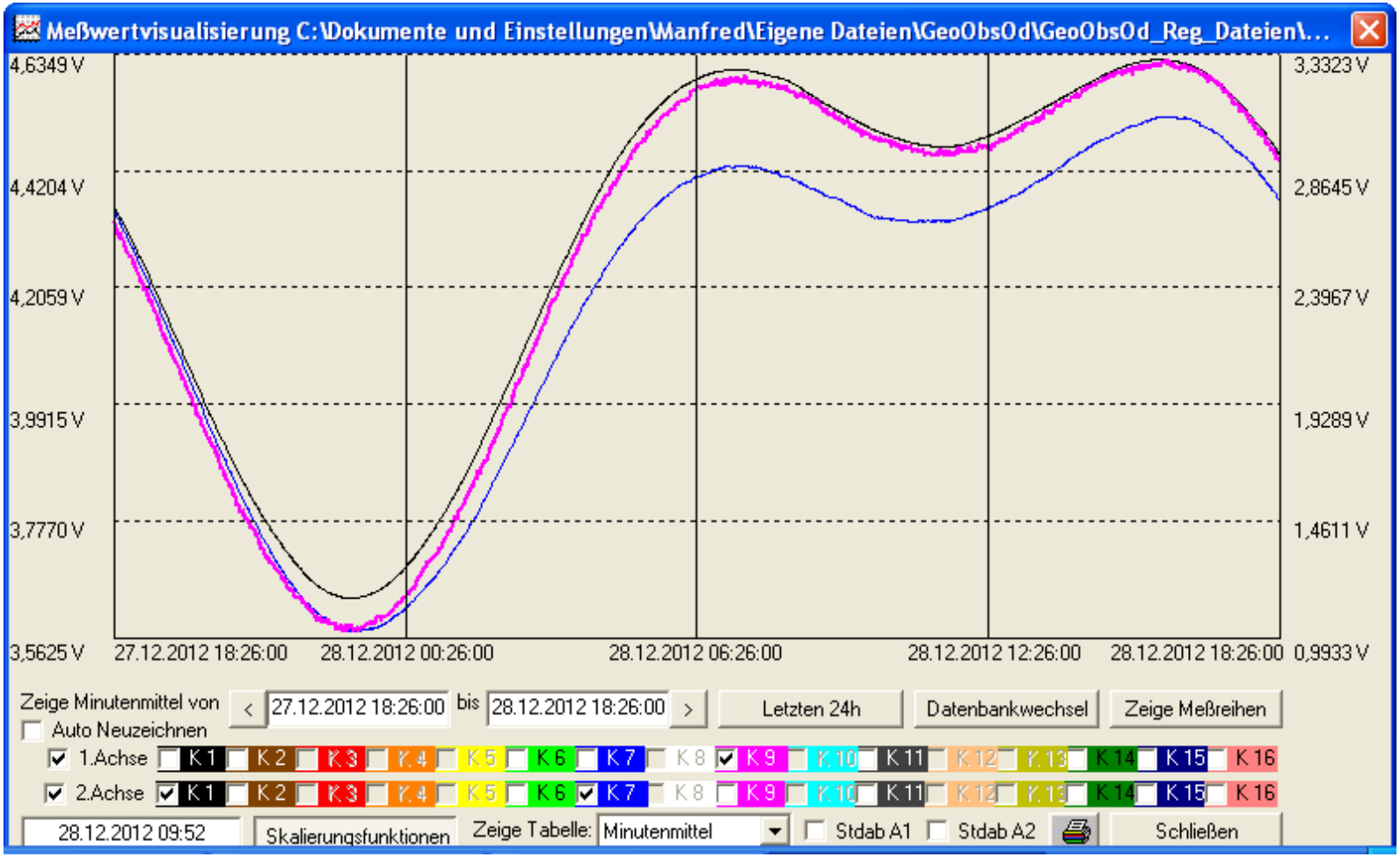
Some applications of the Program- Package *GeoDyn16k*



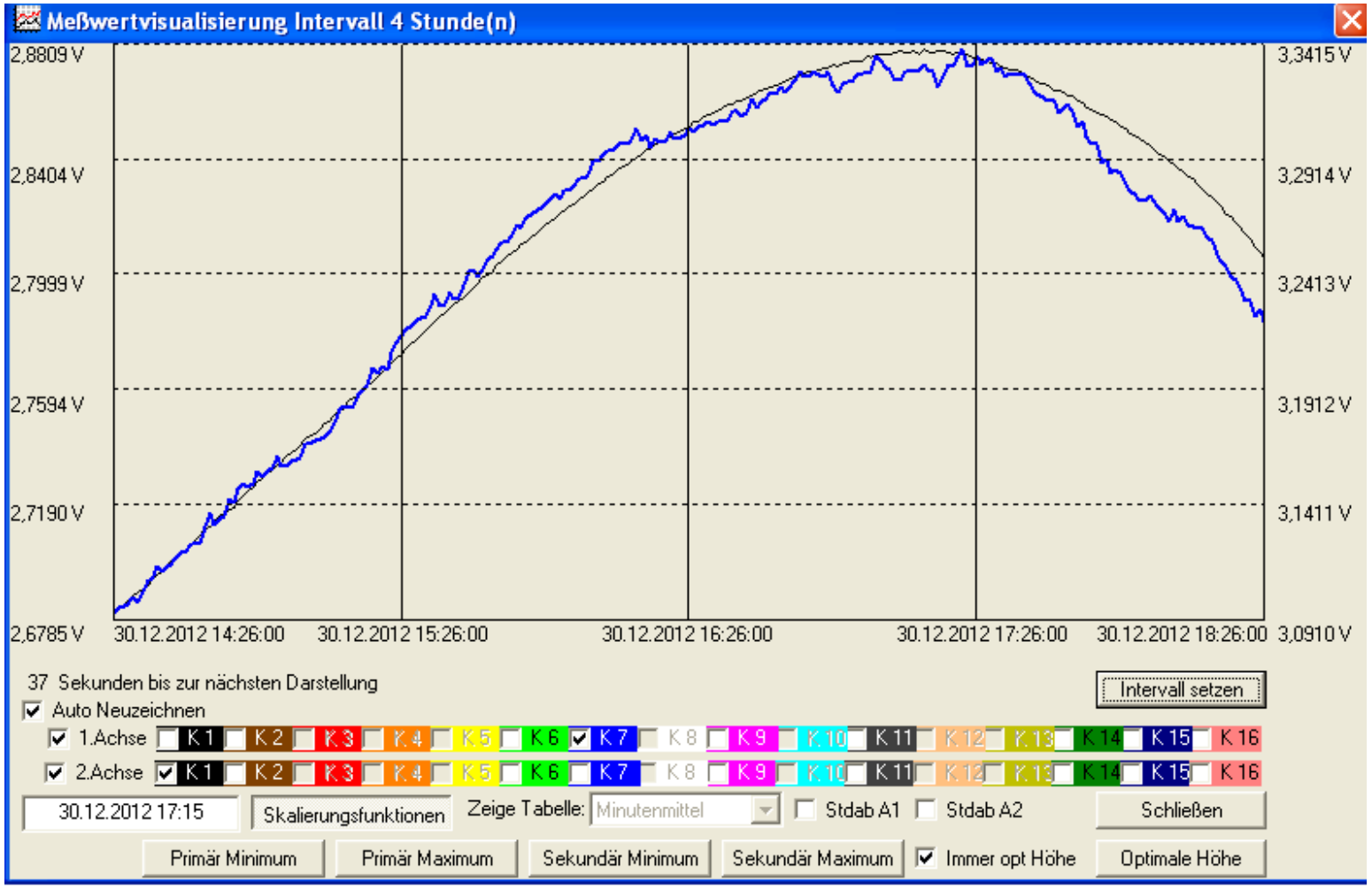
Tools application 3 : observed gravity signal, calculated instrumental drift, drift corrected signal, air pressure.
Investigation of the drift decay after the installation of a gravimeter in the GeoDynLab of the Walferdange Underground Observatory.



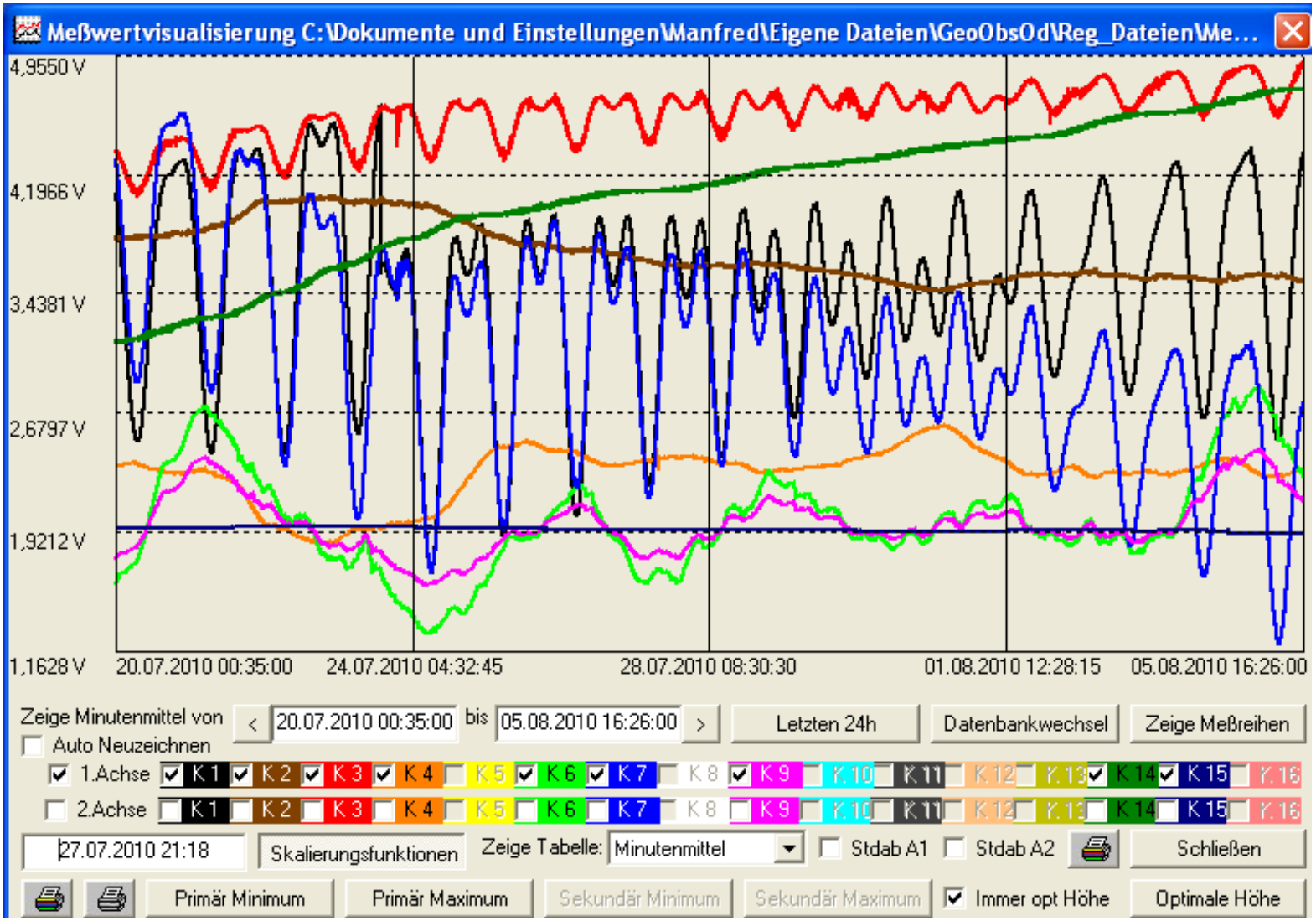
Sample 1a: GeoObservatorium Odendorf, parallel records of two tested LaCoste - Gravimeters with the metrological reference gravimeter A233, additionally records of air pressure, temperatures of chamber air and soil and outside temperature of the station.



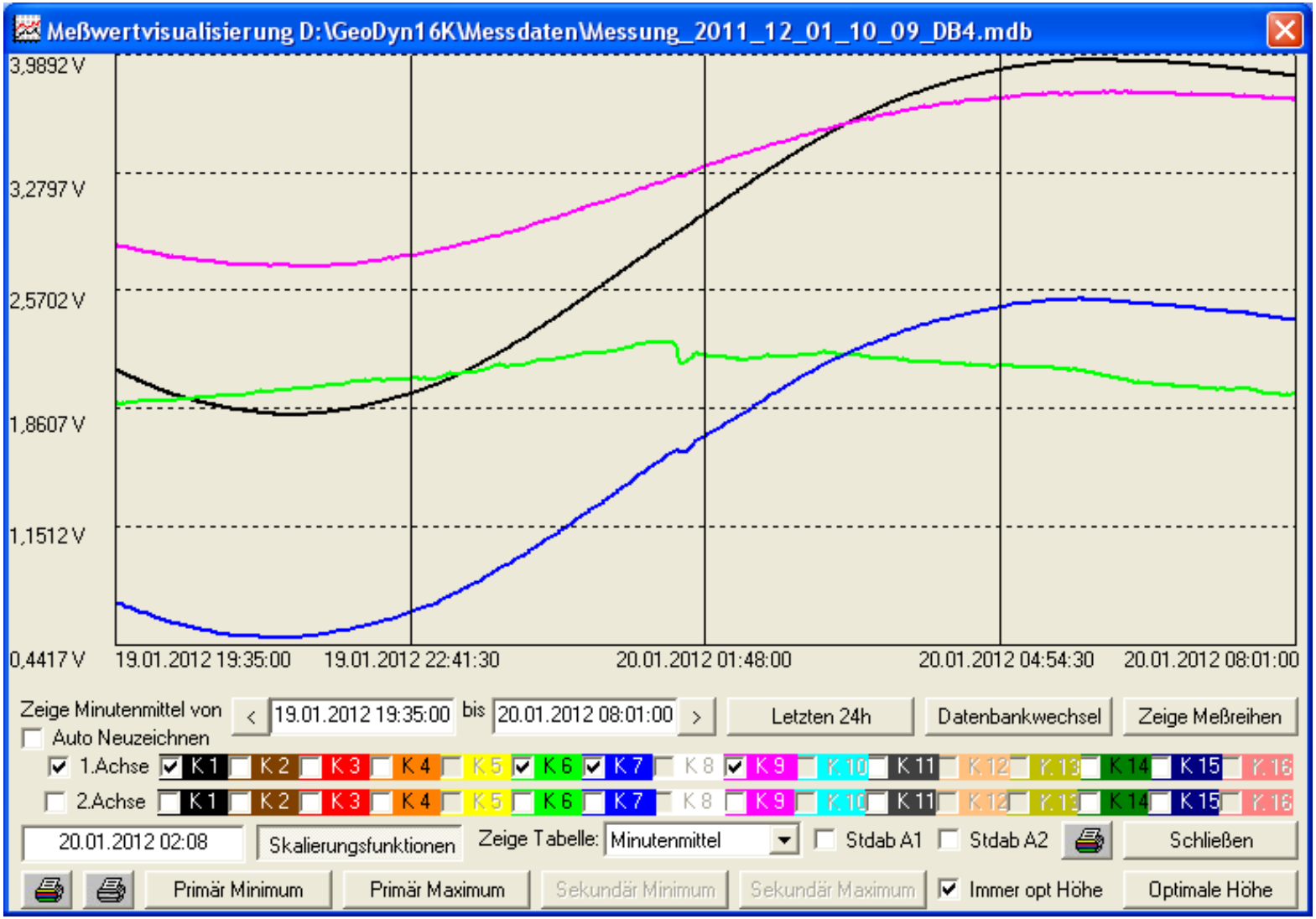
Sample 1b: detailed signal record of three Gravimeters during one day.



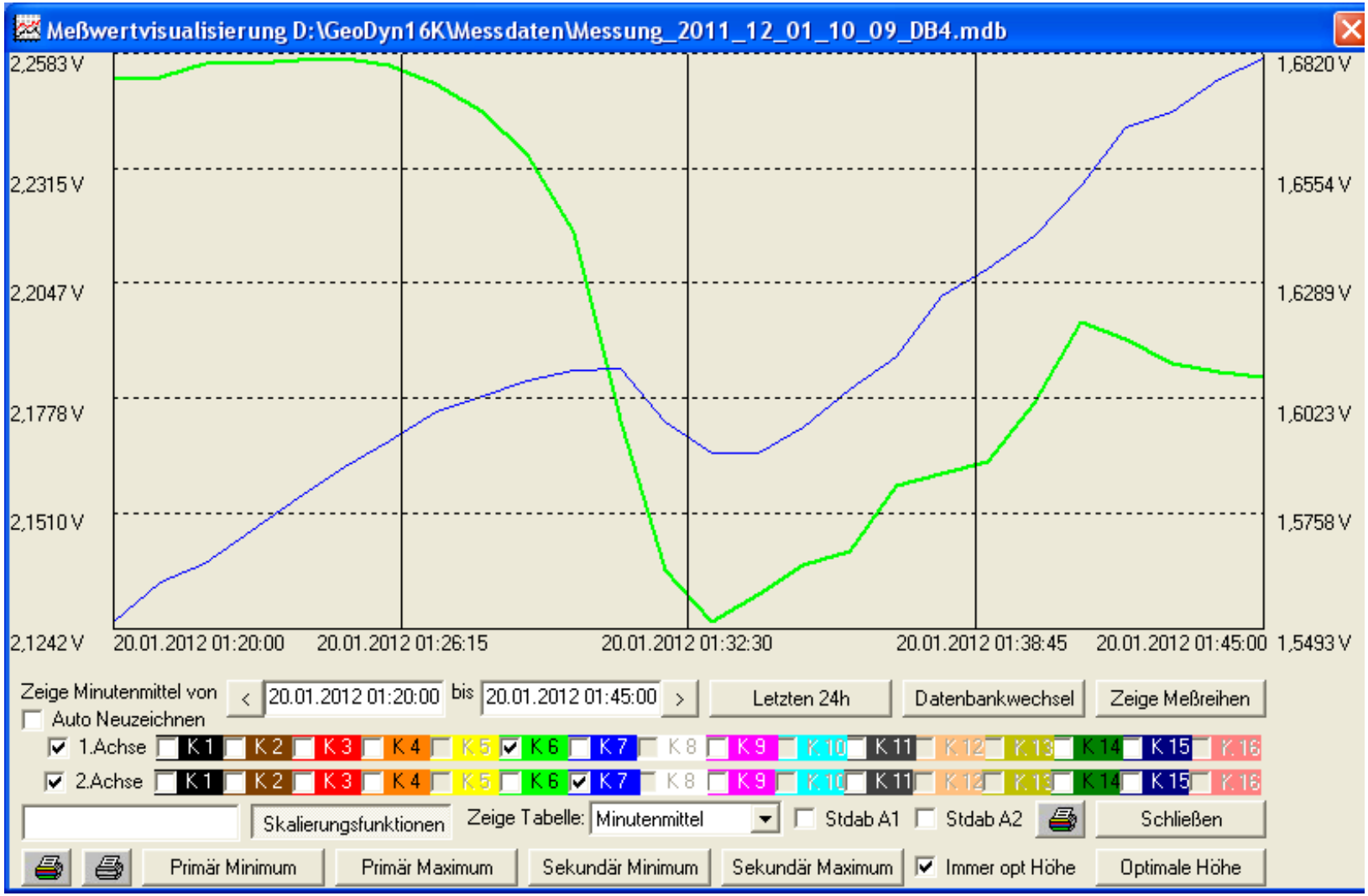
Sample 1c: the four hours record of a defective gravimeter in comparison with the reference gravimeter A233.



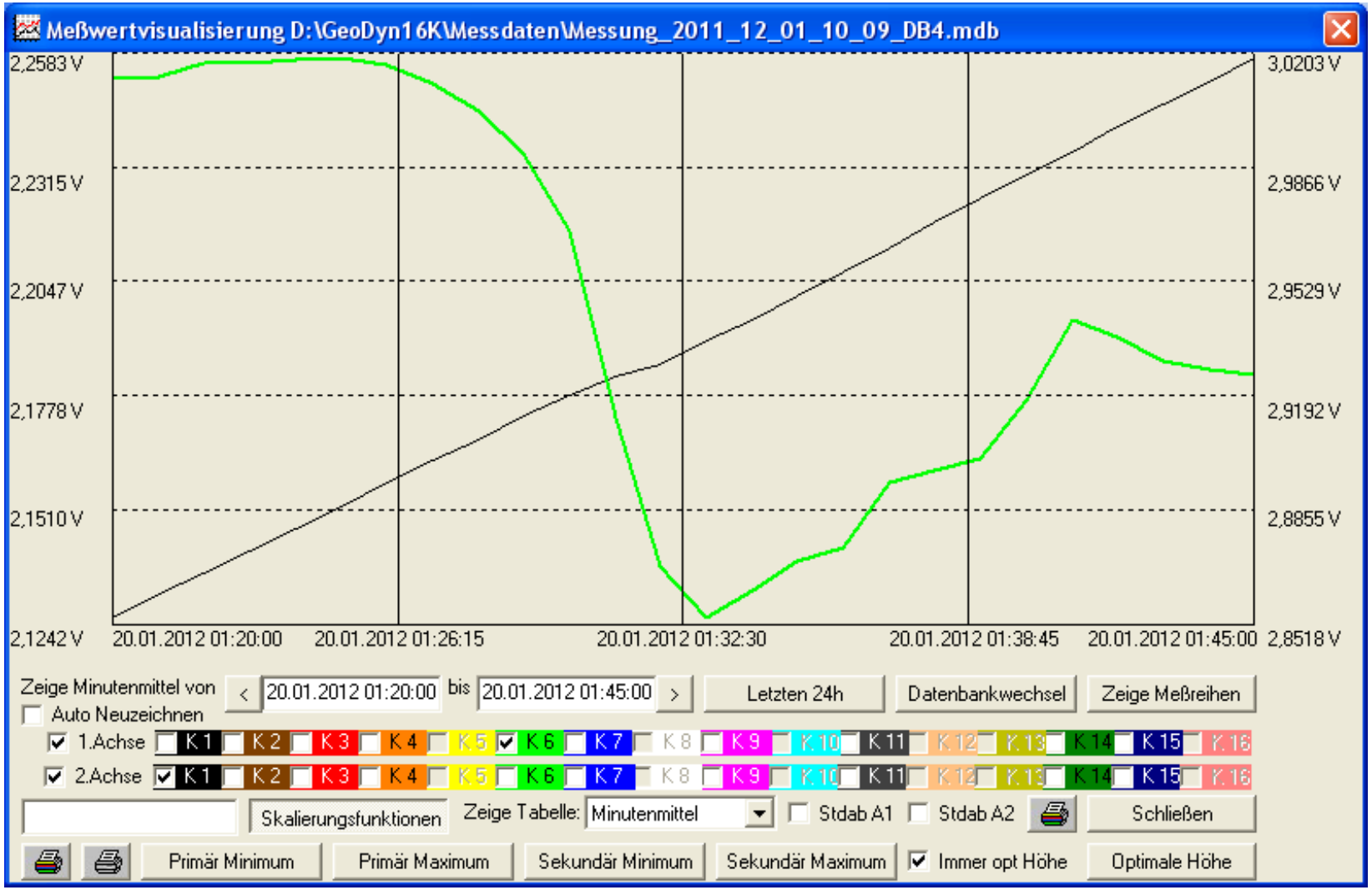
Sample 2: synopsis of the chronological run of nine different quantities .



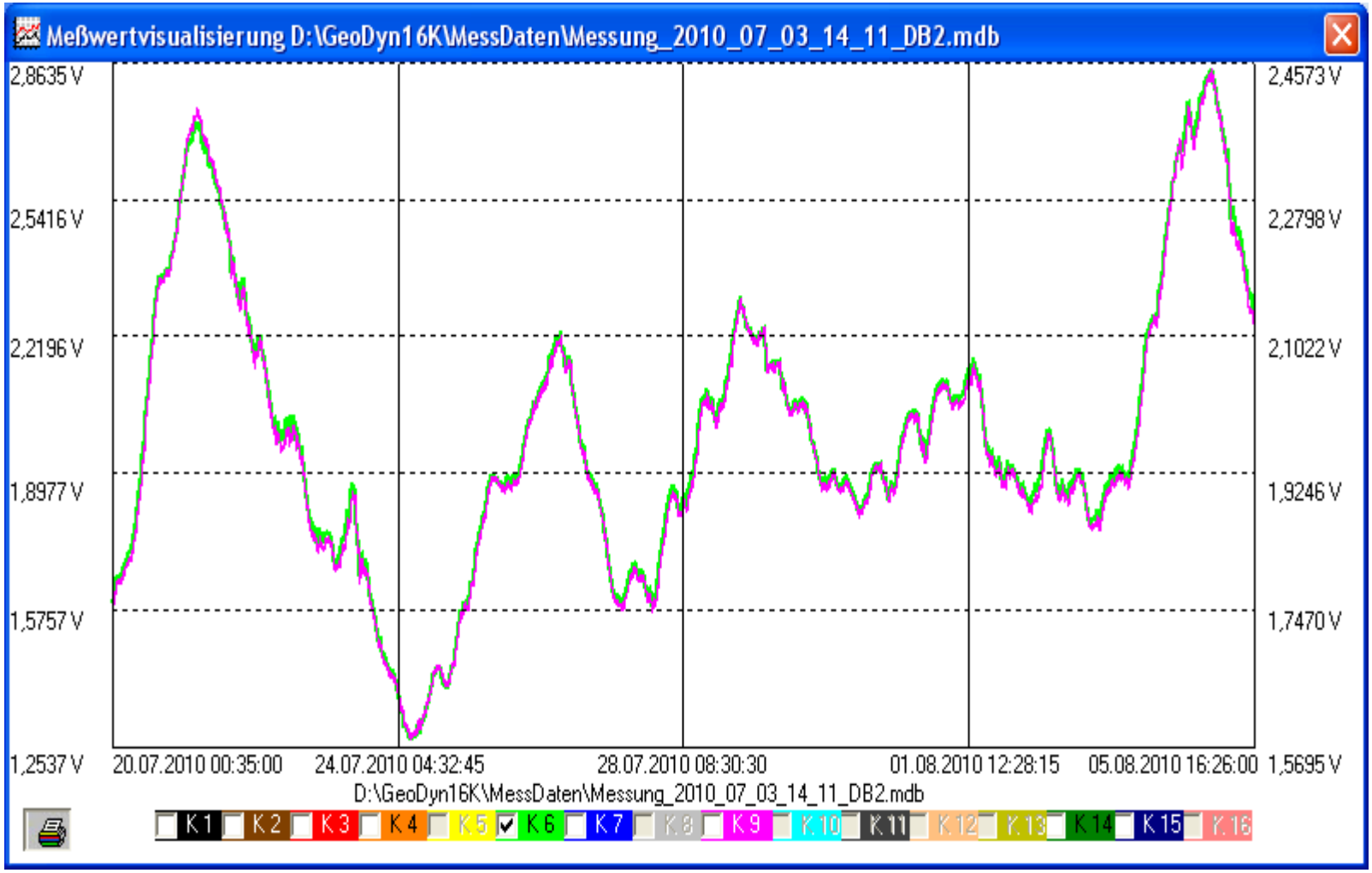
Sample 3a: Testing gravimeters for instrumental air pressure effects, green curve air pressure.



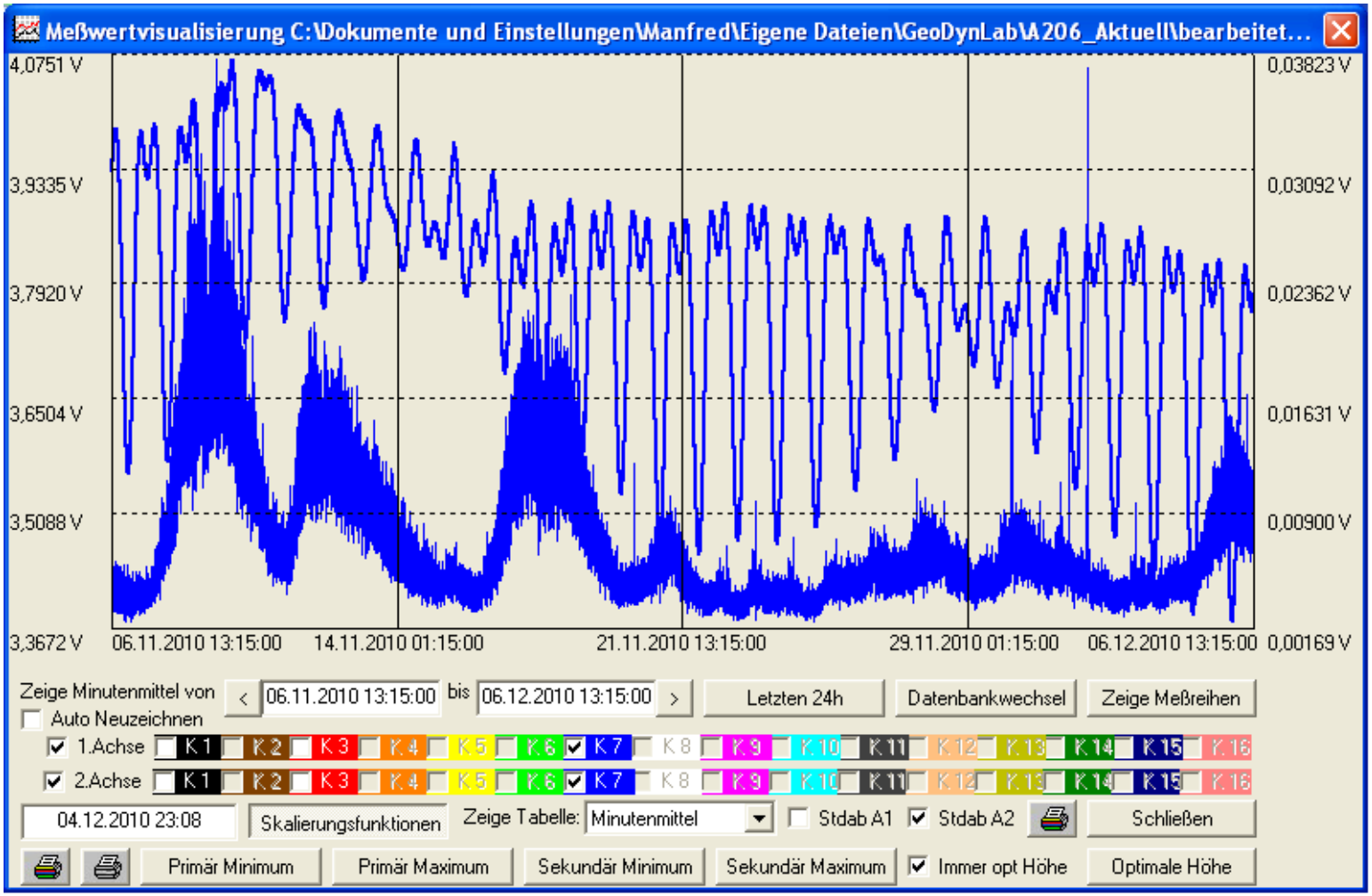
Sample 3b: Instrumental air pressure effect of a leaky gravimeter .



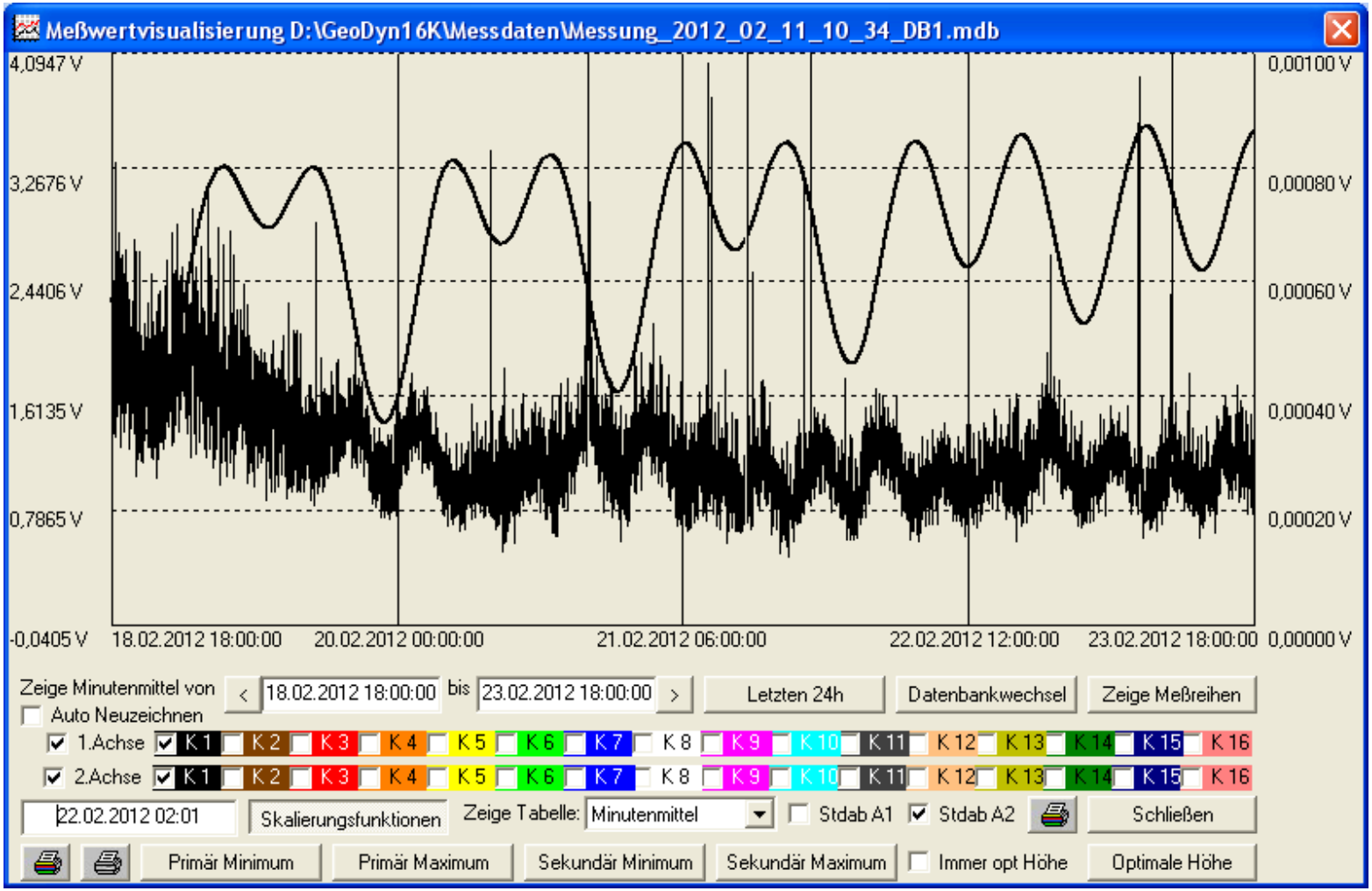
Sample 3c: The corresponding signal run of a hermetically sealed gravimeter.



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.

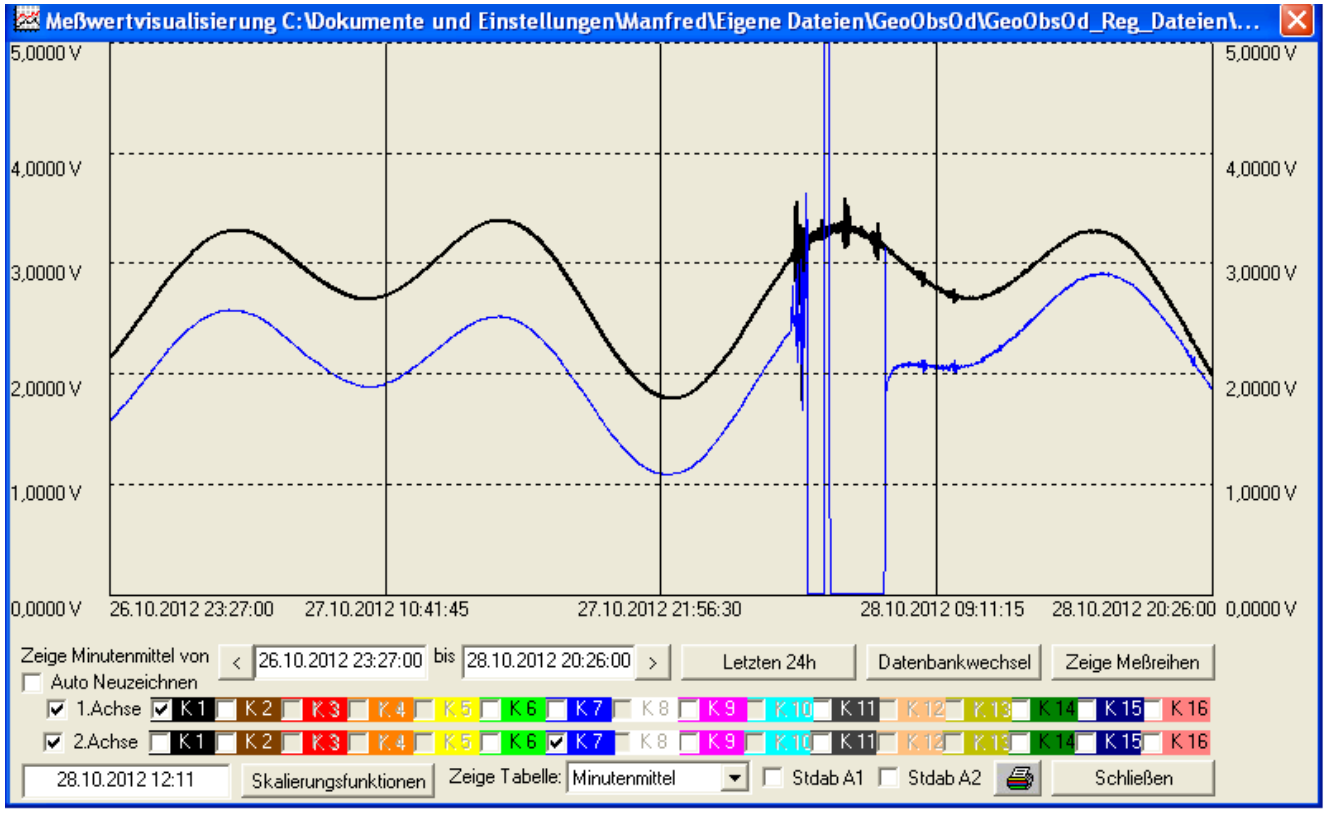


Sample 5: Synchronous display of a gravimeter signal and associated standard errors for a longer time span (here: one month, minute means).



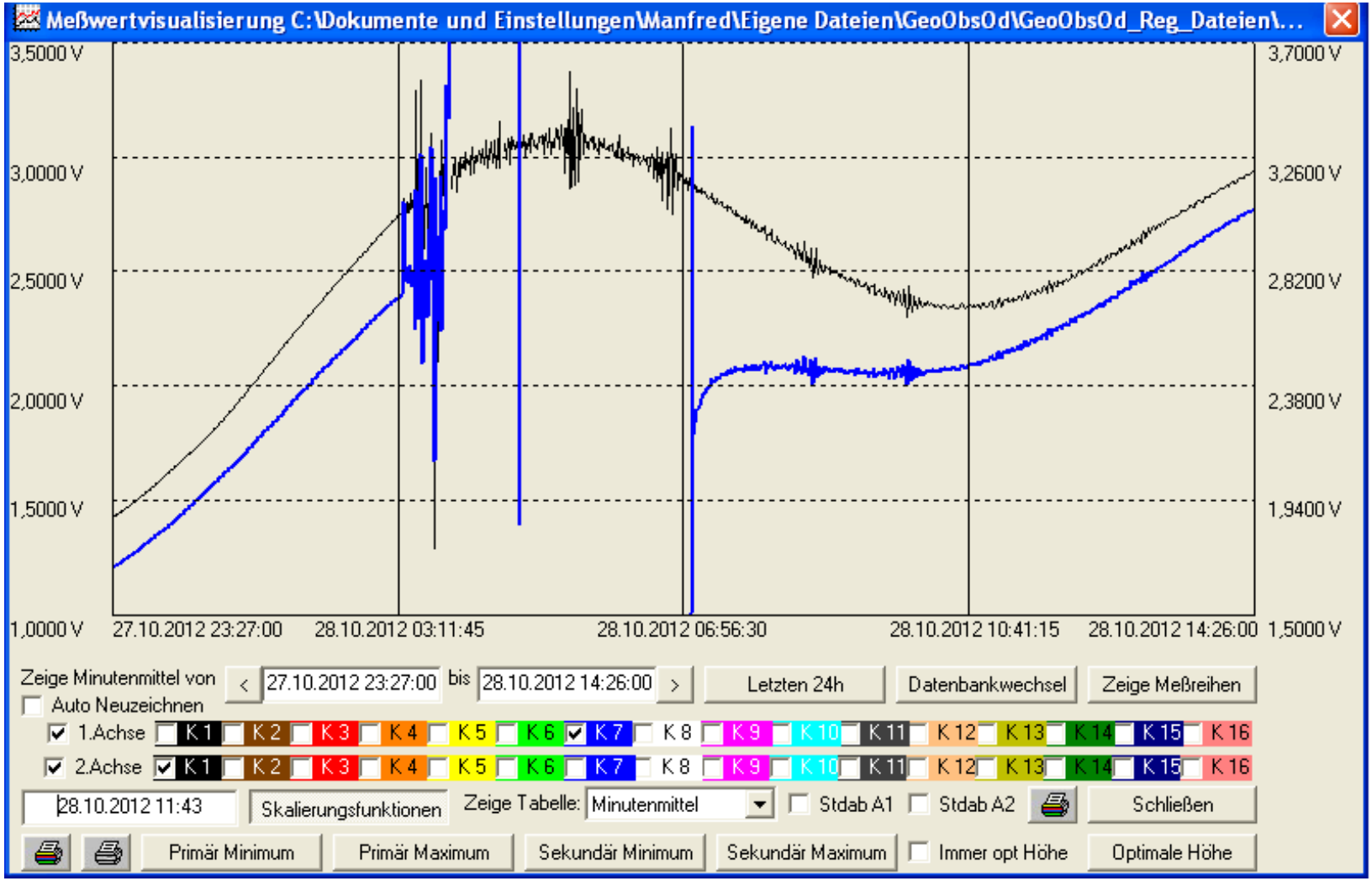
Sample 6: Determination of the true resolution of gravimetric data

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 µGal/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.