1st Workshop on the International Geodynamics and Earth Tide Service (IGETS)

June 18.-20. 2018, Potsdam, Germany

IGETS Data Products (Part II)

Topics:

1. Evaluation of preprocessed data provided by IGETS
2. IGETS data and seismological services,
3. Recent progress in tidal analysis by Klaus Schüller,

1. Data

- **Level 1:** Raw data provided by station operator
  - standard: 1 min (repair code 00)
  - extra: → 1 sec data
- **Level 2:** based on Level 1
  - ICET/UFP
  - User supplied corrected files: uncalibrated?

→ IAG-services: comparison/combination of solutions of different AC's

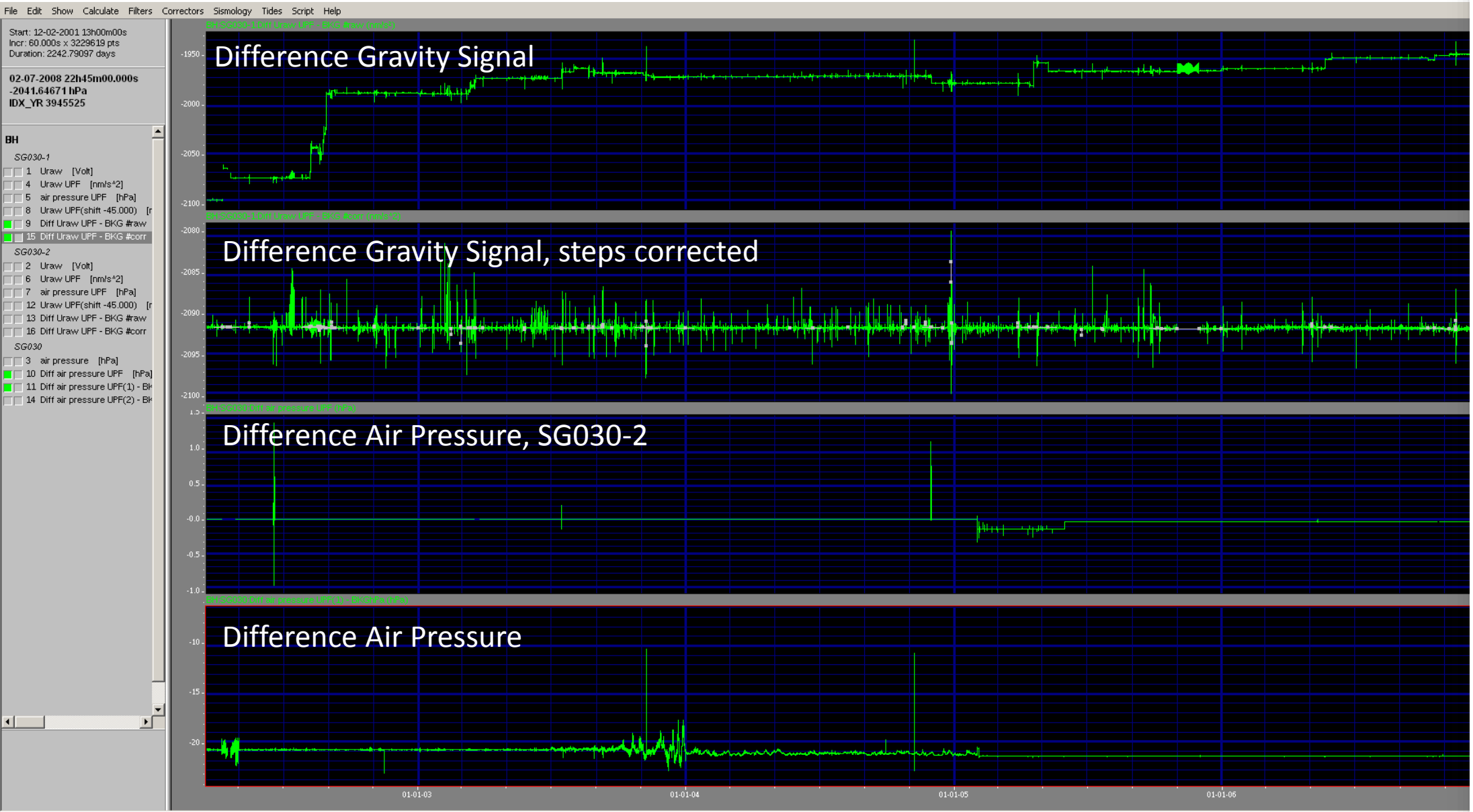
- **Level 3:** based on Level 2
  - Tidal model
  - Atmosphere, hydrology, polar motion

Individual corrections provided to the user!

IGETS REPAIR CODES

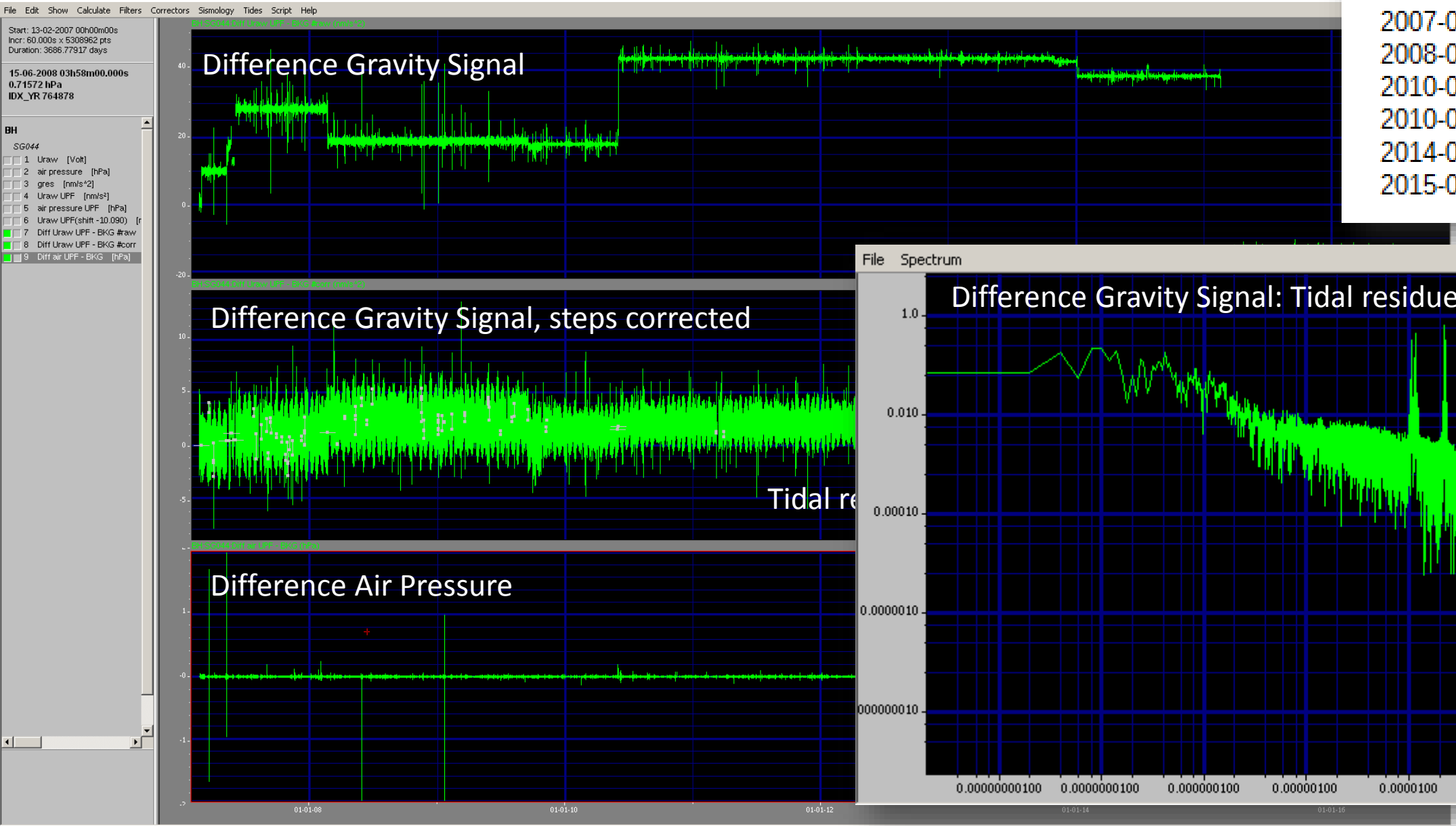
Code	Level	significance	
00	1	raw data (as recorded), decimated to 1 min	no repair prior to decimation (GGP STANDARD). short gaps or spikes shorter than about 10 sec can be filled by linear interpolation between good data points on the raw data (full signal), prior to decimation.
00	1	raw data as recorded at 1 sec, 2 sec ..	no repair, file extension "ggs",
01	1	gaps and disturbances filled with synthetic signal	repair done on raw data, before decimation to 1 min, suggested maximum gap length 2 days
02	1	as 01 + offsets adjusted	repair done on raw data, before decimation to 1 min
11	2	gaps and disturbances filled with synthetic signal	repair done by station operator on data after decimation to 1 min
12	2	as 11 + offsets adjusted	repair done by **station operator** on data after decimation to 1 min
21	2	gaps and disturbances filled with synthetic signal	repair done by staff at **ICET***, on data after decimation to 1 min, prior to tidal analysis
22	2	as 21 + offsets adjusted	repair done by staff at **ICET***, on data after decimation to 1 min, prior to tidal analysis
h1	2	data processed by **user**	one hour data decimated from 1 min
h2	2	data processed by **ICET***	as above, but done by staff at **ICET***

Evaluation of L2-data: Station BH-030-1



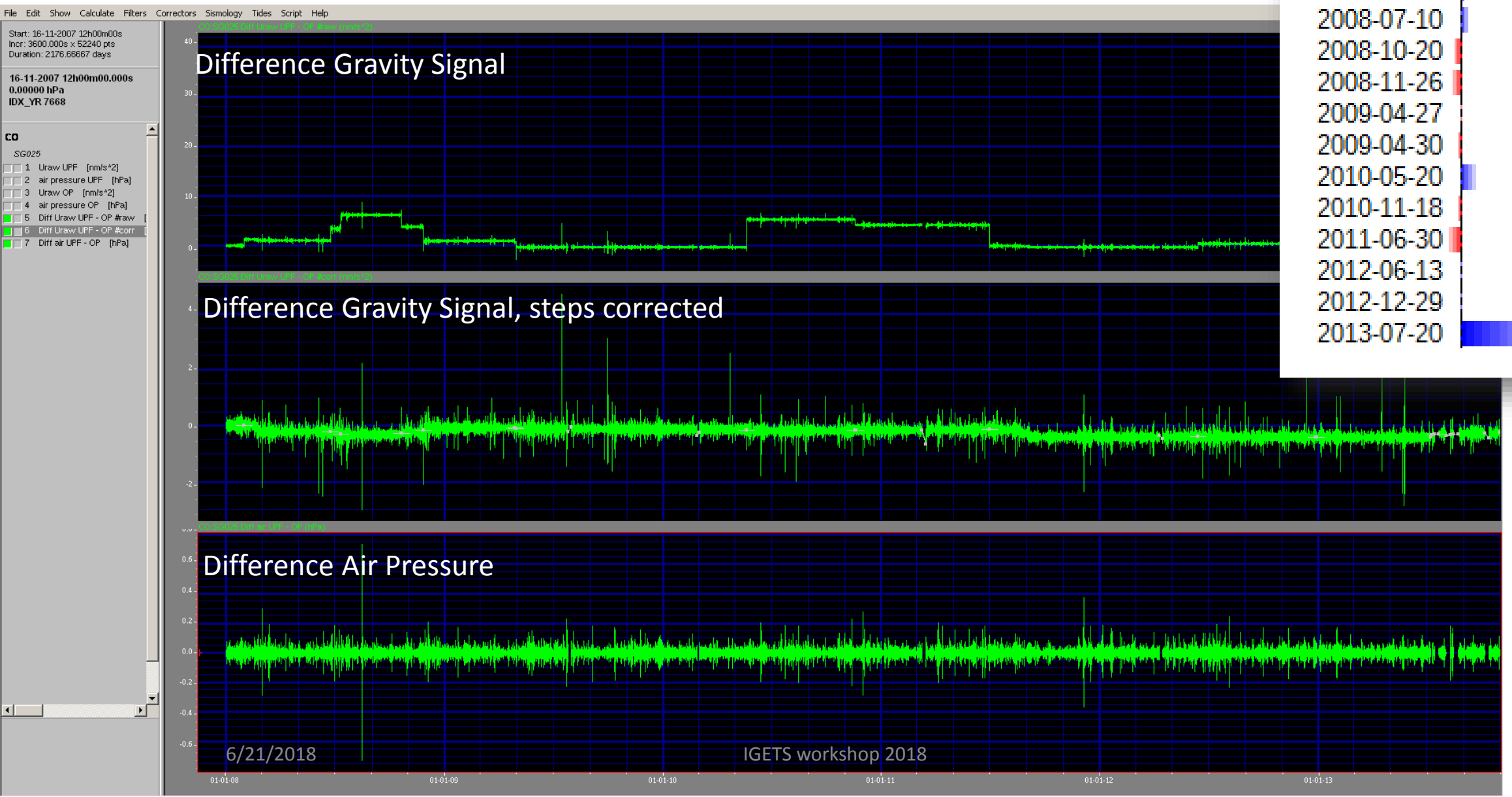
Steps applied [nm/s²]	
2002-01-09	4,3
2002-01-23	1,5
2002-02-08	-14,1
2002-04-09	33,7
2002-04-20	-10,1
2002-08-06	6,4
2002-08-07	25,9
2002-08-16	-6,4
2002-08-21	-0,7
2002-08-25	21,5
2002-08-28	42,5
2002-09-09	1,0
2003-01-01	-0,8
2003-03-10	3,1
2003-03-13	5,0
2003-03-19	8,1
2003-07-15	6,8
2003-08-01	3,9
2003-08-20	-3,6
2003-08-27	-1,4
2003-11-03	-2,2
2003-11-10	-0,8
2003-11-14	-1,4
2004-01-01	0,3
2004-06-22	0,7
2004-12-01	-7,5
2005-04-13	-2,7
2005-04-19	24,3
2005-05-08	-8,9
2005-10-05	0,3
2005-10-11	-0,4
2005-12-01	0,9
2006-01-01	2,1
2006-05-22	9,8
2006-05-31	1,6
2006-10-09	-2,1
2006-10-18	4,8
2006-11-07	1,3
2007-02-10	-2,4
2007-02-12	-1,7
2007-03-01	0,3

Evaluation of L2-data: Station BH-044



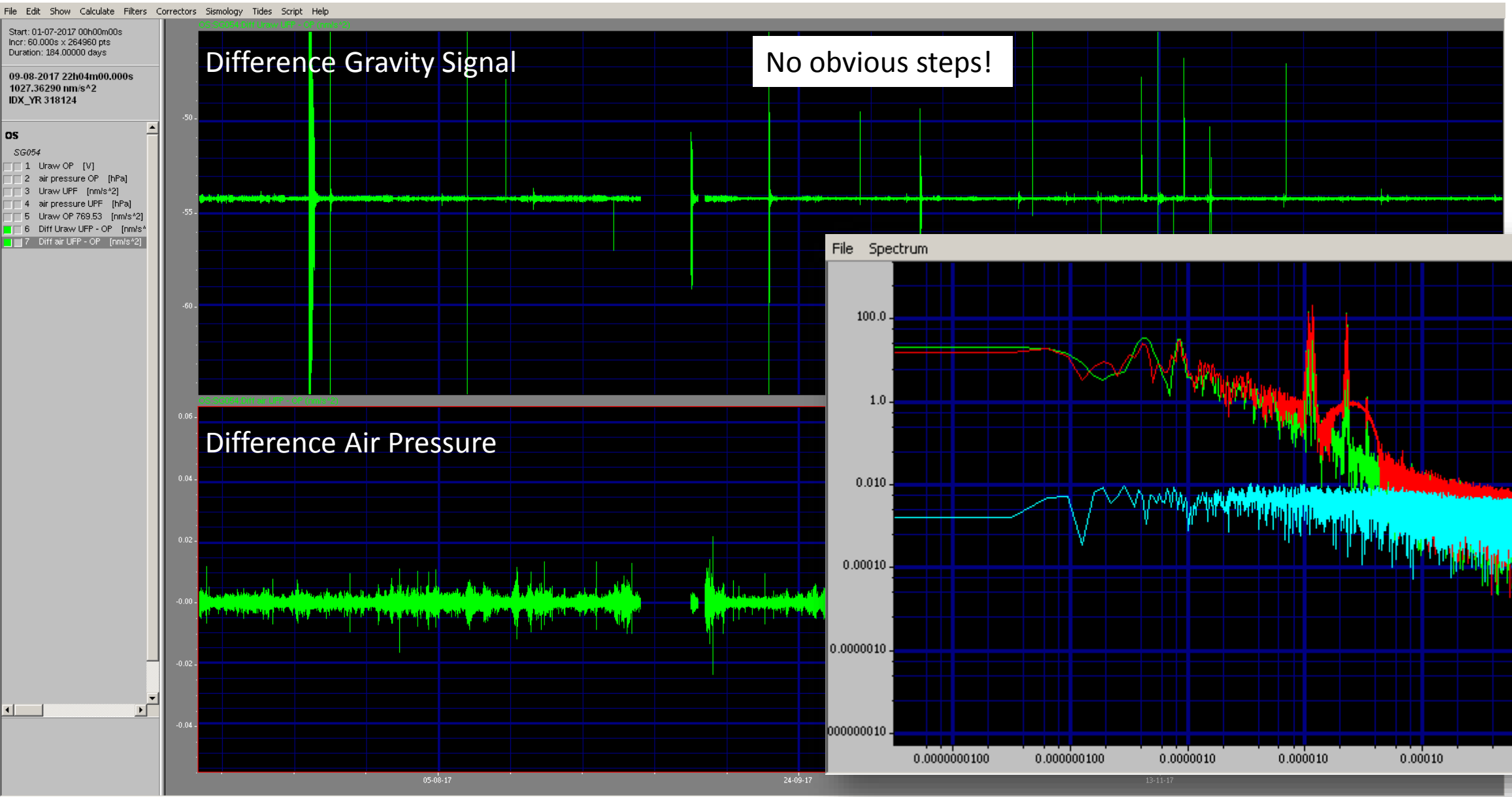
Steps applied [nm/s²]	
2007-02-27	9,9
2007-05-14	7,8
2007-05-24	-5,7
2007-06-04	15,4
2008-02-21	-10,9
2010-05-31	3,6
2010-06-03	21,3
2014-01-04	-4,4
2015-02-19	-53,0

Evaluation of L2-data: Station CO-025



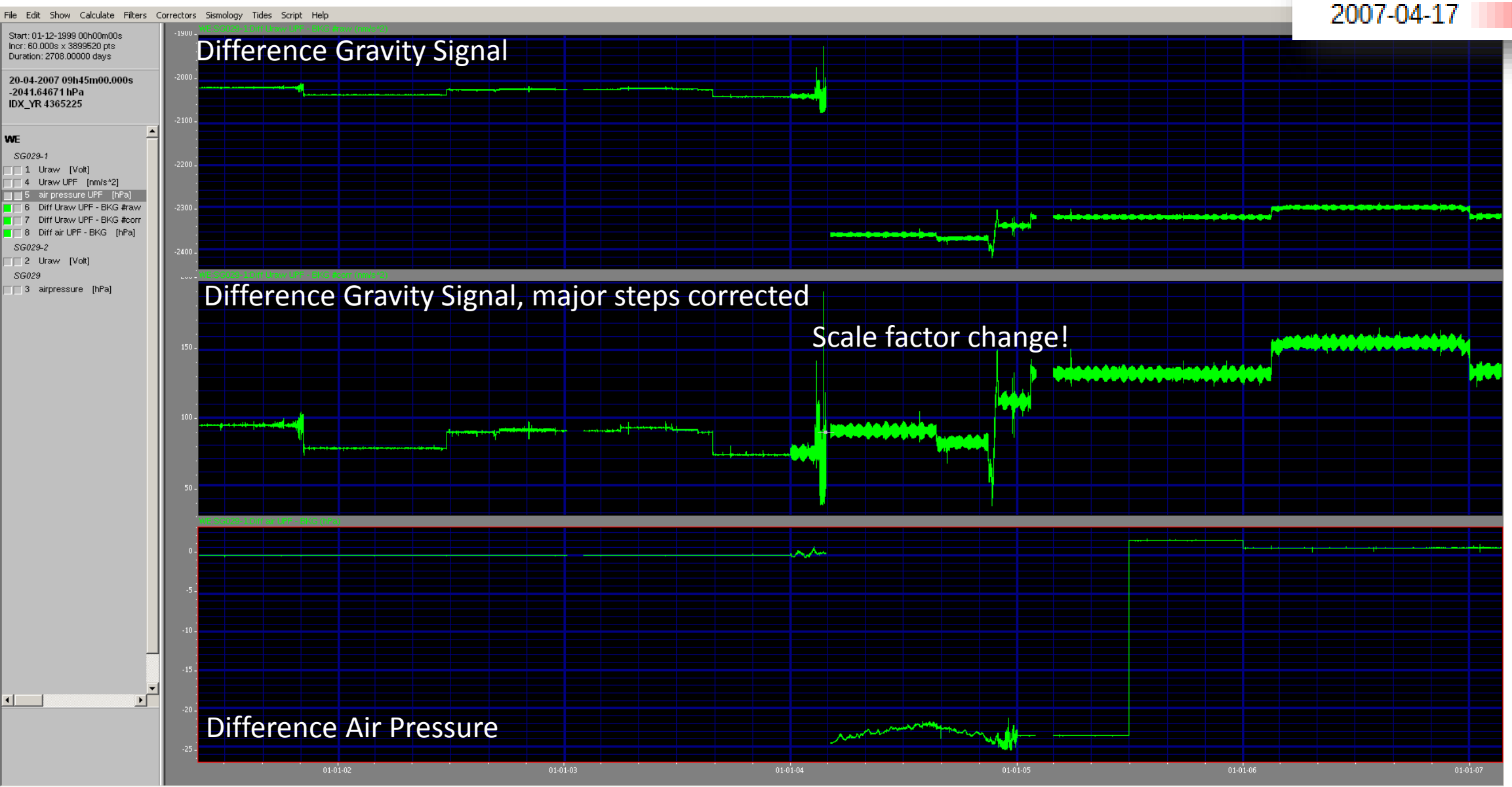
Steps applied [nm/s²]	
2008-01-31	1,3
2008-06-24	2,4
2008-07-10	2,9
2008-10-20	-2,5
2008-11-26	-3,0
2009-04-27	-0,3
2009-04-30	-0,9
2010-05-20	5,6
2010-11-18	-1,1
2011-06-30	-4,2
2012-06-13	0,7
2012-12-29	0,6
2013-07-20	38,7

Evaluation of L2-data: Station OS-054



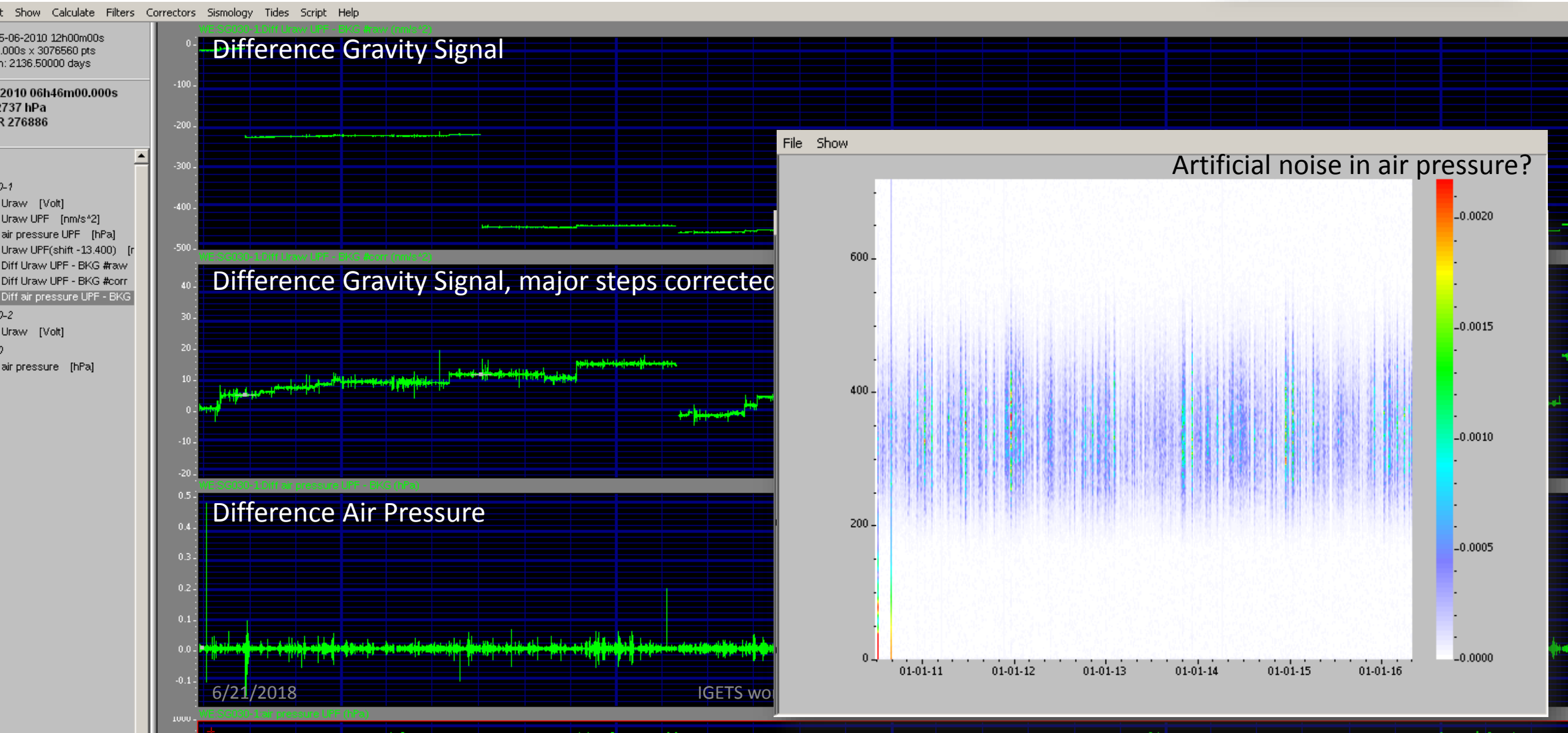
Evaluation of L2-data: Station WE-029

Steps applied [nm/s²]	
1999-12-31	-110,0
2001-03-21	-2000,0
2004-02-27	-346,5
2007-04-17	-2179,2



Evaluation of L2-data: Station WE-030

Steps applied [nm/s²]	
2010-08-25	-230,1
2011-07-05	-239,2



IGETS Data Products (Part II)

Topics:

1. Data

- Evaluation of preprocessed data provided by IGETS
- Documentation of step corrections: Gravity correction function
- Calibration files, Provision and use with L2-data

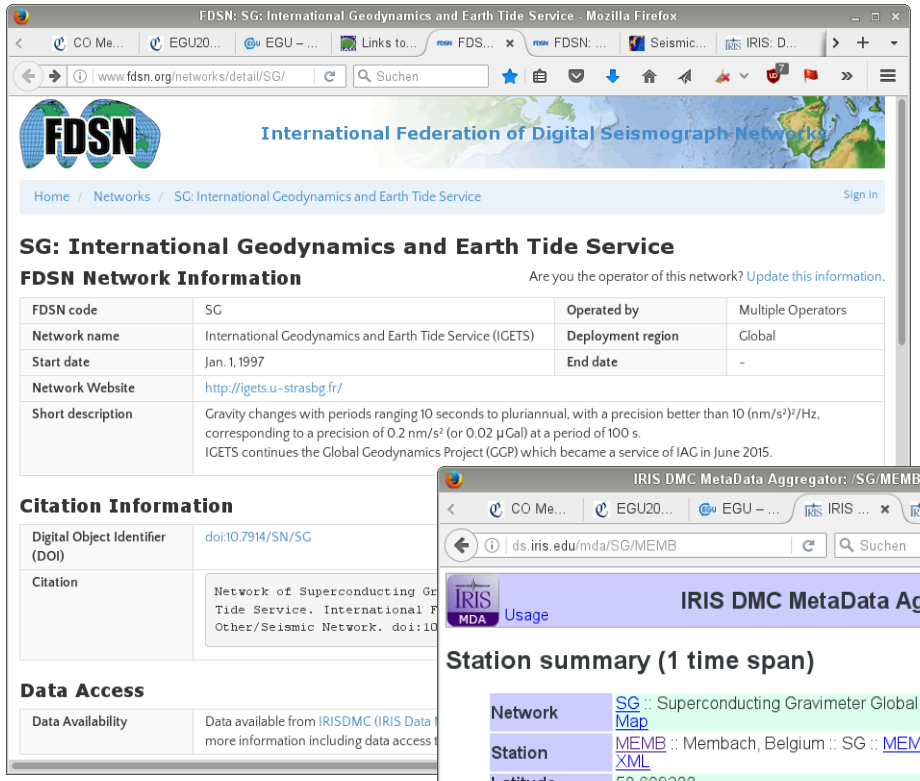
  → Units of gravity signal in processed Data:
  Volts (significant digits!), mV, scaled with one calibration factor

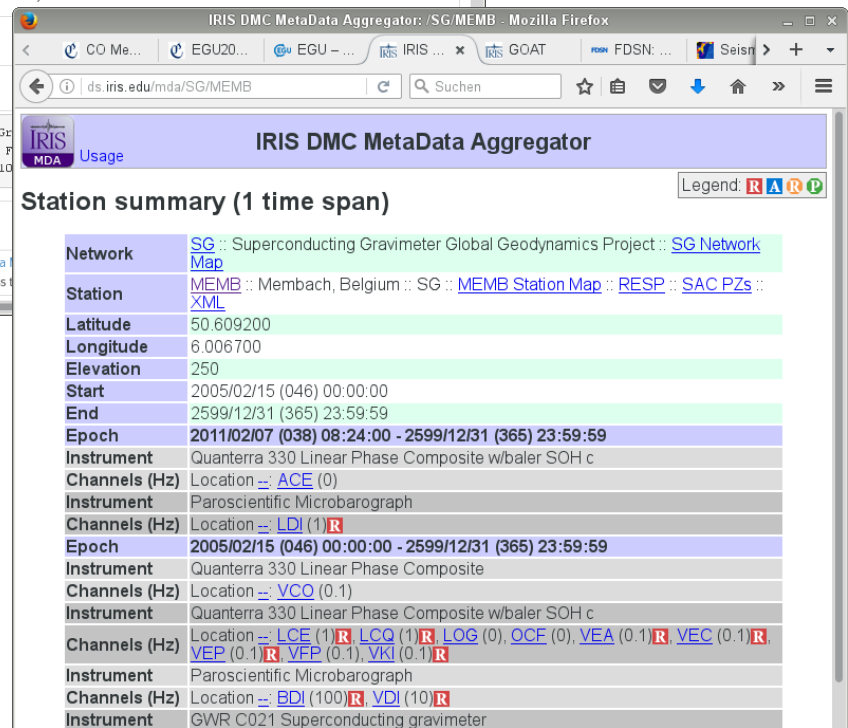
  How to deal with scale factor changes in L2/L3 data?

- Real-time data analysis
- Drift documentation: applied - not applied?

IGETS data and seismological services

- IRIS (Incorporated Research Institutions for Seismology),
  FDSN (International Federation of Digital Seismograph Networks)
- Only three stations:
  - MEMB (high rate), ST, YS (not active)
  - BFO data not scattered across too many network codes: data provided to IRIS/FDSN through network II together with all other BFO channels:
  - http://ds.iris.edu/mda/II/BFO/00/LG1
  - http://ds.iris.edu/mda/II/BFO
- Centralized Conversion to MiniSEED at ISDC?
- Transfer function: How to derive poles/zeros? Nominal values of analogue filter?
- Simple way to provide 1s-Daten?





Experience of sending SG 1-sec data to DMC-IRIS at Strasbourg, France

S. Rosat, J.-P. Boy, J. Hinderer and D. Crossley

Steps to send 1-sec daily SG data to DMC-IRIS from GWR DDAS

STEP 1

- Prepare the response files for the gravimeter and the barometer:

→ Need to know the transfer function of the instrument

→ Compute poles and zeros

→ Sensitivity = 1/ (scale factor in $m/s^2/V$ for the gravimeter or in hPa/V for the barometer)

- Contact Rick Benson (rick@iris.washington.edu) or Mea Edmunds (edmunds@iris.washington.edu) at IRIS to create the station directory (if it does not exist yet) or the channel SG for an existing station: you will then need to send her/him the station coordinates, the response files and the IP address of the server from which the data will be sent to DMC-IRIS.

- On your local server, create a directory containing the data in MINISEED format (see Step 2) and install the **miniseed2dmc** package. **Prior to using this program coordination with DMC is required** and the user must have been assigned a host and port indicating where the data should be sent.

Example: nominal GGP1 RESP file for Strasbourg C026

```
#       +               +-----------------------------------------+
+
#       +               |   Response (Poles & Zeros),  ST ch GGP     |
+
#       +               +-----------------------------------------+
+
#
B053F03     Transfer function type:                 A [Laplace Transform (Rad/sec)]
B053F04     Stage sequence number:                  1
B053F05     Response in units lookup:               M/S**2 - Acceleration in meters
B053F06     Response out units lookup:              V - VOLTS
B053F07     A0 normalization factor:                0.09834064
B053F08     Normalization frequency:                0.0001
B053F09     Number of zeroes:                       0
B053F14     Number of poles:                        8
#       Complex zeroes:
#         i  real          imag          real_error    imag_error
#       Complex poles:
#         i  real          imag          real_error    imag_error
B053F15-18     0  -6.8074080E-01  +1.0569660E-01  +0.00000E+00  +0.00000E+00
B053F15-18     1  -6.8074080E-01  -1.0569660E-01  +0.00000E+00  +0.00000E+00
B053F15-18     2  -6.3407655E-01  +3.1871394E-01  +0.00000E+00  +0.00000E+00
B053F15-18     3  -6.3407655E-01  -3.1871394E-01  +0.00000E+00  +0.00000E+00
B053F15-18     4  -5.3216416E-01  +5.3778676E-01  +0.00000E+00  +0.00000E+00
B053F15-18     5  -5.3216416E-01  -5.3778676E-01  +0.00000E+00  +0.00000E+00
B053F15-18     6  -3.4585748E-01  +7.7406136E-01  +0.00000E+00  +0.00000E+00
B053F15-18     7  -3.4585748E-01  -7.7406136E-01  +0.00000E+00  +0.00000E+00
```

= gain of Bessel 8 pole zero filter

```
#        +                  +---------------------------------------+
+
#        +                  |       Channel Gain,  ST ch GGP        |
+
#        +                  +---------------------------------------+
+
#
B058F03     Stage sequence number:                  1
B058F04     Gain:                                   -1.262600E+06
B058F05     Frequency of gain:                      1.000000E-04 HZ
B058F06     Number of calibrations:                 0
#
#        +               +----------------------------------------+
+
#        +               |   Response (Coefficients),  ST ch GGP     |
+
#        +               +----------------------------------------+
+
#
B054F03     Transfer function type:                 D
B054F04     Stage sequence number:                  2
B054F05     Response in units lookup:               V - VOLTS
B054F06     Response out units lookup:              COUNTS - DIGITAL COUNTS
B054F07     Number of numerators:                   0
B054F10     Number of denominators:                 0
#
```

= 1e9/-792.0 = 1/scale factor

Unit: V/ms-2

```
#         +                     +------------------------------+                     +
#         +                     |   Decimation,  ST ch GGP   |                   +
#         +                     +------------------------------+                     +
#
B057F03     Stage sequence number:                 2
B057F04     Input sample rate:                     1.000000E+00
B057F05     Decimation factor:                     1
B057F06     Decimation offset:                     0
B057F07     Estimated delay (seconds):             0.000000E+00
B057F08     Correction applied (seconds):          0.000000E+00

#         +                  +--------------------------------------+                  +
#         +                  |       Channel Gain,   ST ch GGP      |                  +
#         +                  +--------------------------------------+                  +
#
B058F03     Stage sequence number:                 2
B058F04     Gain:                                  1.000000E+06
B058F05     Frequency of gain:                     1.000000E-04 HZ
B058F06     Number of calibrations:                0
#
#         +                  +--------------------------------------+                  +
#         +                  |   Channel Sensitivity,   ST ch GGP   |                  +
#         +                  +--------------------------------------+                  +
#
B058F03     Stage sequence number:                 0
B058F04     Sensitivity:                           -1.262600E+12
B058F05     Frequency of sensitivity:              1.000000E-04 HZ
B058F06     Number of calibrations:                0
```

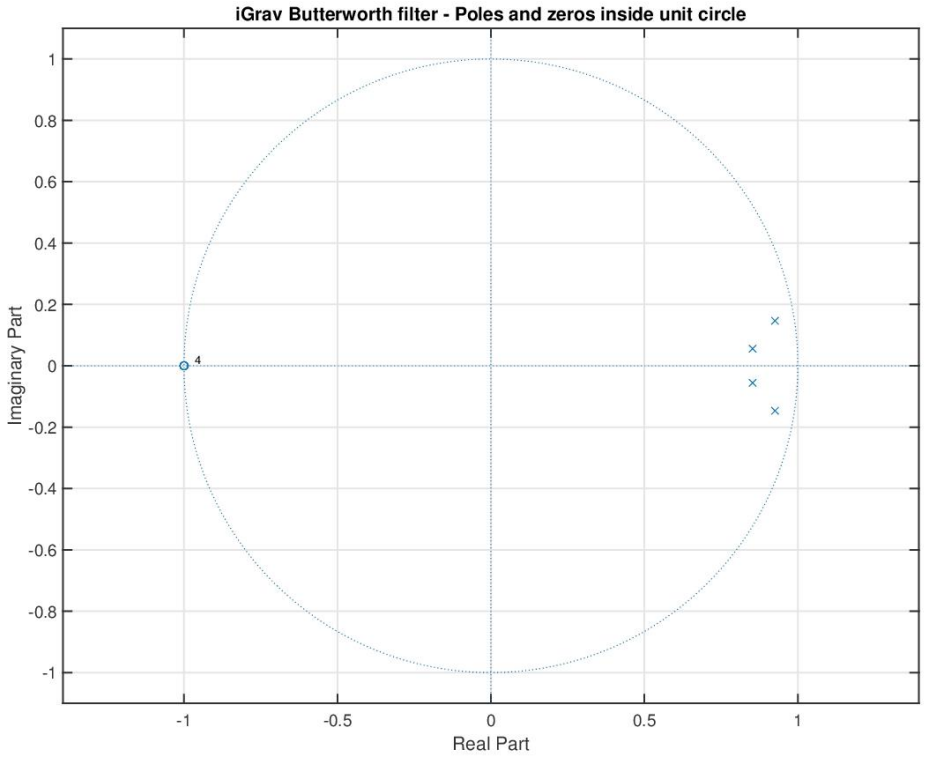
= set as 1e6 for GGP (counts/V)

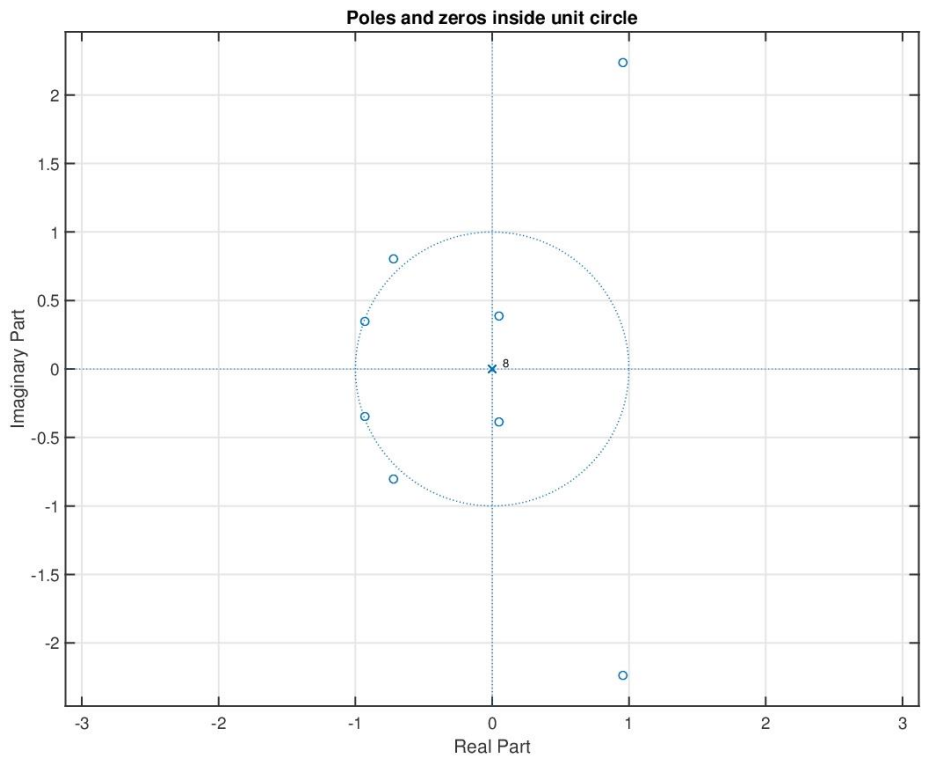
= total response in counts / m s-2

A nominal response file for iGrav and iOSG:

- Butterworth analog filter → poles and zeros

- FIR filter consisting of 69 terms (Analog to Digital Converter triggered at 8 Hz) (for iGrav and iOSG manufactured after January 2015) or FIR filter consisting of 85 terms (Analog to Digital Converter triggered at 10 Hz) (for iGrav manufactured before January 2015) → zeros only (filter coefficients provided by GWR)





STEP 2: preparation of MINISEED files on a Linux computer

SG C026 — GWR DDAS — Local data server

T-Soft 1-sec daily files
G1yymmdd.026
GGP1, Baro1, TIDE, Baro2

convert
*(script to call **COR_DAY1s.f**)*

Preterna daily files
Styymmdd.dat
GGP1, Baro1

dat2mseed
*(script to call **ggp2mseed.c**)*

package to be installed on a linux computer to convert from PRETERNA to MINISEED

MiniSEED daily files
Styymmdd.mseed

send2iris
*(script to call **miniseed2dmc.c**)*

DMC/IRIS

Automatic scripts running everyday

Scripts and packages available at: **http://igets.u-strasbg.fr/Documents/ggp2iris.zip**

Alternative treatment of SG 1 sec data

SENDING MONTHLY FILES TO IGETS

1. Many users have sent earthquake data to GGP following major earthquakes. These files have been used extensively by scientists studying the normal modes or free oscillations. The reason non-seismologists have used them is their availability as simple ASCII files, and they were posted on the GGP website for immediate download.

2. It is trivial for data providers to prepare 1 sec files by month and send them on a regular basis to IGETS at the same time as the 1 min files are sent. Example files are available for example in directory ***/Apache-Point/ap046/Level1/2009***
in files like ***IGETS-SG-SEC-ap046-20090400.zip***.

3. All that is required at IGETS is to apply a similar script file as ***ggp2mseed.c*** to prepare the MINISEED version, and then send to IRIS using ***miniseed2dmc.c***.

4. Although this requires 2 extra processing steps at IGETS, surely it can be done quite easily.

5. The advantage to data providers is obvious. The only downside is the 1 month delay in getting the data directly to IRIS for immediate processing, but fewer people are doing this for every large earthquake anyway.

Recent progress in tidal analysis by Klaus Schüller: ETERNA ET34-ANA-Vnm

- No update of Eterna 3.4 package since 1997, DOS binaries not executable on Windows 7+
- Initiative by K. Schüller (HYCON) in 2014 welcome:
  Updated version with new features based on source code of version 3.4

New Features (selected):

- Hypothesis free modelling of the higher degree of the tidal force development (TGP V3-V6)
- Integrating the DDW-H and DDW-NHi Earth models in addition to WDZ up to degree 6
- Fully integrating degree 1 tidal potential.

```
1**************************************************************************
 **********                                                      **********
 ********** H Y C O N  RELEASE 2.1                              **********
 **********                                                      **********
 **********                                                      **********
 ********** AUTHOR : DR. KLAUS SCHUELLER                        **********
 **********                                                      **********
 **********                                                      **********
 **********                                                      **********
 **********                                                      **********
 **********                                                      **********
 **********                                                      **********
 **************************************************************************

0STANDARD-ANALYSIS
 ******************
 DEFINITION OF THE INPUT VARIABLES
 *********************************
0  1.CONTROL PARAMETER SET
 ========================
    0    0    0    0    0    1    3    0    0    0    3   12    1    1    0
0  2.CONTROL PARAMETER SET
 ========================
```

- Redesign of the stochastical model now fully based on least squares and statistical theory
- Binaries 32- and 64-bit MS-Windows compatible with Vista, 7, 8, 10, based on FTN95 from Silverfrost

Updated Version of ETERNA ET34-ANA-V70

- ET34-X-V70 now is applicable for all tidal components without any restrictions
- ET34-X-V70 now comprises all degrees 1 to 6 of the tidal potential development (TGP)
- ET34-X-V70 supports the following Earth models for all components

  Dehant-Defraigne-Wahr-H (DDW-H)

  Dehant-Defraigne-Wahr-Nhi (DDW-Nhi)

  Wahr-Dehant-Zschau (WDZ)
- ET34-X-V70 now provides a model for “Free Core Nutation (FCN)” for all components including strain

Important Reference:

> “Canonical Wave Grouping as the Key to Optimal Tidal Analysis” by
> Ducarme, B. and Schueller, K., to be published in BIM 150 soon

represents an important source of information for this release. Many of the ideas and derivations of this paper have been implemented in ET34-X-V70.

Changes in ETERNA ET34-ANA-V70: TGP structure

Providing a high-resolution structure for the constituents of the TGP

- by associating new symbol names to constituents derived from the Moon's ascending node and perigee as well as annual modulations.
- Implementation of this structure into the TGPs of Hartmann, Wenzel 1995, Kudryavtsev 2003 and Tamura 1987
- General structure of a V_2- wave group xxxx of the Tide Generating Potential (TG):

- low frequency annual modulation xxxxa => $\omega - h + p_s$
  - ○ low frequency Moon's perigee V3:xxxx- => $\omega - p$
    - ▪ low double nodal frequency xxxx-- => $\omega - 2N'$
      - • low nodal frequency xxxx- => $\omega - N'$
        - ○ **tidal main constituent xxxx => ω**
      - • high nodal frequency xxxx+ => $\omega + N'$
    - ▪ high double nodal frequency xxxx++ => $\omega + 2N'$
  - ○ high frequency Moon's perigee V3:xxxx+ => $\omega + p$
- high frequency annual modulation xxxxb => $\omega + h$ - p_s

- *s mean tropical longitude of the Moon,*
- *h mean tropical longitude of the Sun,*
- *p mean tropical longitude of the lunar perigee,*
- *$N' = -N$ negative mean tropical longitude of the lunar ascending node and*
- *p_s mean tropical longitude of the solar perigee.*

Changes in ETERNA ET34-ANA-V70: Wave groups

Rayleigh-Periods in tropical years for resolving the general wave group structure:
The table values are generated by calculating for each row the difference in angular velocity of the parameters ω, N' ,2N', p of column "Main tide xxxx" and the column parameters ± N', ±2N',± p, ± (h-p_s) and then replacing the results by the associated periods in tropical years.

-(h-p_s) xxxxa	-p V3:xxxx-	-2N' xxxx--	-N' xxxx-	Main tide xxxx	N' xxxx+	2N' Xxxx++	p V3:xxxx+	h-p_s xxxxb
				frequ.				
1.00005*	8.85	9.31	18.61	ω	18.61	9.31	8.85	1.00005*
0.949	6.00	6.20	9.31	N'		9.31	16.86	1.06
0.903	4.54	4.65	6.20	2N'			179.34	1.12
0.898	4.42	4.54	6.00	p				1.13

Changes in ETERNA ET34-ANA-V70: Wave groups

- **Reference potential functions and associated wave groups**
  - Definition of reference potential functions
    - V20, V21, V22, V33, V44, V55, V66
      - uniquely cover the tidal frequency domain
      - each representing only 1 unique tidal frequency band.
- **Reference wave groups**
  - Wave groups belonging to reference potential functions

V_{nm}	long periodic	1/1-diurnal	1/2-diurnal	1/3-diurnal	1/4-diurnal	1/5-diurnal	1/6-diurnal
Degr.n/ord.m	0	1	2	3	4	5	6
1	V_{10}	V_{11}					
2	$\boldsymbol{V_{20}}$	$\boldsymbol{V_{21}}$	$\boldsymbol{V_{22}}$				
3	V_{30}	V_{31}	V_{32}	$\boldsymbol{V_{33}}$			
4	V_{40}	V_{41}	V_{42}	V_{43}	$\boldsymbol{V_{44}}$		
5	V_{50}	V_{51}	V_{52}	V_{53}	V_{54}	$\boldsymbol{V_{55}}$	
6	V_{60}	V_{61}	V_{62}	V_{63}	V_{64}	V_{65}	$\boldsymbol{V_{66}}$

Changes in ETERNA ET34-ANA-V70: Wave groups

- **Non-reference or satellite wave groups**
- Definition of non-reference or satellite wave groups
  - representing different potential degrees but the same orders as the reference potential functions
  - sharing the same tidal frequency bands
    - V31 in V21,
    - V32 in V22
    - ……etc
- **Implementation reference and satellite wave group**

$$Option\ code \in \{degree\ 1,\ degree\ 3,\ degree\ 4\ , degree\ 5,\ degree\ 6\}$$
$$= \{\ O_1 \quad O_3 \quad O_4 \quad O_5 \quad O_6\ \}$$
$$= O_1 O_3\ O_4\ O_5\ O_6$$

with options $O_i \in \{0,1,2,3\}, \quad i \in \{1,3,4,5,6\}$

- **Option $O_i = 0$: Reference wave group modelling**

standard modelling of reference wave group $xxxx_k$ by means of an Earth model like DDW-NHi, DDW-NH, WDZ-Hi, where the constituents of V_{im_k} in $xxxx_k$ are normalized with their amplitude factors according to eq.(6a

- **Options $O_i > 0$: Non-reference wave group modelling:**
  - **Option $O_i = 3$** : for each reference wave group $xxxx_k$, extended over $\Delta\omega_k$ and belonging to degree n_k, modelling all constituents of degree $i \neq n_k$ in so-called "satellite"wave groups"Vi: $xxxx_k$;
  - **Option $O_i = 2$** : for each reference wave group $xxxx_k$, extended over $\Delta\omega_k$ and belonging to degree n_k and order m_k, modelling all constituents of degree i,

Changes in ETERNA ET34-ANA-V70: Wave groups

General form of a degree based wave group definition

Name/ symbol	lower freq. bound	upper freq. bound	degree	order	option code
$xxxx_i$	$f_{l,i}$	$f_{u,i}$	n_i	m_i	$O_{1i}O_{3i}O_{4i}O_{5i}O_{6i}$
	cpd	cpd			
O1	0.929390	0.929960	2	1	23221
	Generated	wave groups			Description
V11	0.58	1.48	1	1	add all V1 tides in O1-range to V11
V3:O1	.929390	.929960	3	1	Satellite wave group
V41	0.58	1.48	4	1	add all V4 tides in O1-range to V41
V51	0.58	1.48	5	1	add all V5 tides in O1-range to V51
V6	0.58	1.48	6		add all V6 tides in O1-range toV6

Changes in ETERNA ET34-ANA-V70: Potential functions under correlation aspects

Highly correlated subsets:

- Subset I of even potential degrees : $\{\boldsymbol{V_2}, V_4, V_6\}$ with principle degree $\boldsymbol{V_2}$
- Subset II of odd " : $\{V_1, \boldsymbol{V_3}, V_5\}$ with principle degree $\boldsymbol{V_3}$

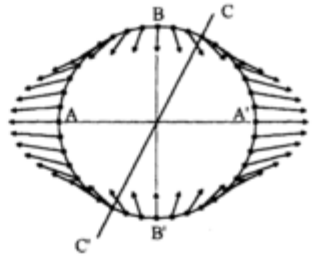
Conclusion for analysis:

- **First analyze potential functions with minimum correlation -> TIER1 priority**
- **If possible add remaining potential functions -> TIER2 priority**

V_{nm}	long periodic	1/1-diurnal	1/2-diurnal	1/3-diurnal	1/4-diurnal	1/5-diurnal	1/6-diurnal
Degr.n/ord.m	0	1	2	3	4	5	6
1	V_{10}	V_{11}					
2	$\boldsymbol{V_{20}}$	$\boldsymbol{V_{21}}$	$\boldsymbol{V_{22}}$				
3	V_{30}	V_{31}	V_{32}	$\boldsymbol{V_{33}}$			
4	V_{40}	V_{41}	V_{42}	V_{43}	$\boldsymbol{V_{44}}$		
5	V_{50}	V_{51}	V_{52}	V_{53}	V_{54}	$\boldsymbol{V_{55}}$	
6	V_{60}	V_{61}	V_{62}	V_{63}	V_{64}	V_{65}	$\boldsymbol{V_{66}}$

ETERNA – Earth Tide Analysis and... | Advanced Calibration Method...

http://ggp.bkg.bund.de/eterna/



HOME NEWS ABOUT

The enhanced Earth Tide Analysis and Prediction Program ET34-ANA-Vmn

Introductory remarks by

Klaus Schueller, Research Initiative for Tidal Analysis (RITA)

The objective of this initiative is to acknowledge and preserve the extraordinary intellectual and technical work of my colleague and friend Prof. Dr.-Ing. habil. Hans-Georg (Schorsch) Wenzel who passed away a long time ago.
Therefore, the intention is to maintain and enhance a comprehensive and sustainable platform for Earth tide analysis which will meet the nowadays requirements of the tidal user community all over the world.

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News

Maintenance update for ET-ANA-V52 available!

Coming soon: Version ET34-ANA-V60

Download of Version ET34-ANA-V52 avail-