Experiment with the Bonn Scintrex CG-5

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Outline

- Introduction to CG-5 (Autograv Scintrex)
- Atmospheric Effects
- Data Corrections, Drift and Data Analysis
- Experiments (Bonn and Bad-Homburg)
- Tilt Experiments
- Summary and Outlook
**Autograv Scintrex CG-5**

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Fused quartz using electrostatic nulling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution (Reading)</td>
<td>1 Micro-Gal</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5 Micro-Gal</td>
</tr>
<tr>
<td>Operating Range</td>
<td>8000 Milli-Gal</td>
</tr>
<tr>
<td>Drift</td>
<td>0.02 mGal/day</td>
</tr>
<tr>
<td>Tilt Compensation</td>
<td>±200 arcsec.</td>
</tr>
<tr>
<td>GPS receiver</td>
<td>Standard &lt; 15m, CG-5 clock synchronisation</td>
</tr>
<tr>
<td>Key fob</td>
<td>30 m (line of sight)</td>
</tr>
<tr>
<td>Smart Battery (fan)</td>
<td>2 x 6.6 (Ah), Full day op.</td>
</tr>
<tr>
<td>Weight</td>
<td>8 kg. (portable)</td>
</tr>
</tbody>
</table>

**AUTOgrav: All effective corrections have been automatically considered!**
Autograv Scintrex CG-5 contd.

- **Dis-avdantages:**
  - Keyboard *sensitivity*! (2 sec. Pause!)
  - Firmware *stability*! (hanging)
  - Single observation [1 Hz] has an accuracy of around 80 Microgal!

- Standard deviation (Time window of 60 sec ~ 5 Micro-Gal)
Atmospheric effects

- Pressure

\[ \Delta g_p = -0.3 \cdot \Delta p \, [\muGal] \]


✓ **Neglectable** (if pressure changes are less than 17 [hPa])
Atmospheric effects

- Temperature

\[ TEC = Tempco \cdot Temp \]

-0.122 mGal/mK  Measured in vaccum!
Atmospheric effects

- Precipitation: changes in the mass!

- Atmospheric effects can be neglected in the normal conditions!
Data Correction and Analysis

Corrections:

- Drift (Manual or Automatic)
  - Automatically corrected!

- Tide
  - Internal (Longman-Formula, precision problem!)
  - External (ETERNA precision less than 5 Microgal)

- Tilt (less than 200 arcsec.), recommended less than $\pm 10$ arcsec.
  - Automatically corrected!

- Temperatur changes (Internal and External)
  - CG-5 is very sensitive to temperature change
  - Display heating system
  - Tilts more than 200 arcsec. cause strong temp. changes

- Filters
  - Noisy sample filter
  - Seismic noise filter

BLACK BOX!
Drift free?

- **CG-5** has a drift of **0.02 [mGal/day]** (ref. Scintrex Ltd.)
Experiment (Bonn, May 2013)
Experiment (Bonn, May 2013)

Tilt x,y [arcsecs]

Temp. [mK]

MJD [days]
Experiment in Bad-Homburg Castle

Castle Bad-Homburg
Different CG-5s
Bad-Homburg Experiment (Bonn vs. Koblenz)
Bad-Homburg Experiment (Thüringen vs. Stuttgart)
Bad-Homburg Experiment (Hamburg vs. BKG)
Tilt

Piza, Italy
Tilt Experiment

Disc Thicknesses [mm]

8 [°]

1 [°]
Tilt Experiment procedure (angle & time)

1) Level CG-5 & measure for one [h]
2) Turn off and Tilt it with the different tilt angles & waiting for 100 [min]

3) Remove disc, turn on, level it and take measurement for at least 24 [h]

Finding the critical angle
Tilt Experiment at Bonn, diff. angles
Tilt Experiment at Bonn, diff. angles
Tilt Experiment at Bonn, diff. angles

Tilt 14.4 mm - DT 100 minute

Tilt 17.3 mm - DT 100 minute

Graphs showing changes in gravitational field and tilt over time.
Tilt Experiment at Bonn, diff. angles
1) Level CG-5 & measure for one [h]

2) Turn off and Tilt it with the angle 8 (Disc 23 [mm]) & waiting for 10, 30, 60, 90 [min]

3) Remove disc, turn on, level it and take measurement for at least 24 [h]
Tilt Experiment, angle 8 [°] & diff. time
Tilt Experiment, angle 8° & diff. time
Functional relationship (tilt time & instrument stabilization)

<table>
<thead>
<tr>
<th>Tilt time [min]</th>
<th>Offset[mGal] / Stab. Time [hour]</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>-55 / 0.5</td>
</tr>
<tr>
<td>30</td>
<td>-43 / 12.6</td>
</tr>
<tr>
<td>60</td>
<td>-85 / 19.82</td>
</tr>
<tr>
<td>90</td>
<td>-89 / 19.18</td>
</tr>
</tbody>
</table>

\[ s(\Delta t) = 0.81 + 0.66\Delta t - 0.005\Delta t^2 \]
Functional relationship contd. (Delft)

**Tilt angle of 8 [°]**

<table>
<thead>
<tr>
<th>Tilt time [min]</th>
<th>Offset [mGal] / Stabilization time [h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>-40 / 3.6</td>
</tr>
<tr>
<td>30</td>
<td>-120 / 6.7</td>
</tr>
<tr>
<td>70</td>
<td>-150 / 11.5</td>
</tr>
<tr>
<td>90</td>
<td>-180 / 14.4</td>
</tr>
</tbody>
</table>

\[ s(\Delta t) = 3.72 + 0.14\Delta t - 0.00008\Delta t^2 \]
Reasons (CG-5 Sensor ?)

- Quartz-Glass spring
- Two plates
- Electrostatic nulling
- Test mass

Source: IGM (Mr. Schuler)
Solution

✓ Caution in transport

✓ Check the “USER Check Voltage” before starting to take measurement
  ✓ If “USER check Voltage” approaches zero, wait at least 14-20 [h]

✓ Use a Gyroscope!

✓ Other ideas
Autograv is very sensitive instrument to the tilt!

Critical angle and time, and stabilization function have been found for the Bonn CG-5.

Causes for the tilt offset are not clear exactly!

Shake effect is another important effect, but has not been investigated!
Thank you for your attention!