Some remarks and explanations after the „IFE Absolute Gravity Campaigns 2003 in the Fennoscandian Land Uplift Area“

Wind generates always short-periodic seismic noise. Trees and other vegetation or build-up objects are swinging or vibrating in the wind. Therefore, it is preferable to measure absolute gravity in buildings which are not too exposed to wind impacts. The vicinity to high buildings and also trees might shake the whole area around. Massive grown rock as a base for the station would help to a great extent. ***Ålesund*** is a very positive example which respect to this issue.

Ocean microseisms are generated in shallow waters in coastal regions. The wave energy can be converted directly into seismic energy either through vertical pressure variations, or by the smashing surf on the shores, which have the same period as the water waves (5 to 15 seconds). The energy may damp down with distance to the sea (e.g., in Northern Germany with the sandy soil) but may also propagate hundreds of km inland when transmitted through rock.
This kind of disturbance is very bad for the FG5 gravimeters. The so-called superspring (device to isolate the free-fall experiments from the environment to provide a pseudo-inertial system) will react by swinging in a resonance mode.
The best way to overcome this problem is to stay a few km off the coast line (but often it is not possible). The station ***Ålesund*** is extremely close to the sea. But we learnt that it is possible to do satisfactory measurements if the environmental conditions (not only the local conditions) are calm. We had such a period (some 36 h) during our occupation of that station. Extended visits to sites helps to avoid observations on days with high microseisms.

Man-made microseismic noise (especially in cities, e.g., due to traffic or noisy industry) can partly by avoided by using weekends and nights for the absolute measurements. Because many free-fall experiments are performed to determine a mean gravity value, the impact on the final result will largely be cancelled out due to the averaging procedure. Stronger impulses (shocks due to shutting doors, etc.) may excite the superspring from time to time and it may happen that the spring will never really come to a not moving stage (depending on the frequency of disturbances and their amplitudes). In such a case, we can not exclude that the final value (mean) is biased due to the incoming noise and the resulting unfavourable spring behaviour. In **Trysil**, all that kind of trouble can be excluded.

Instrumental vibrations of the absolute gravimeter (dropping chamber) during each free-fall experiment are generated by the release of the dropping assembly (5 Hz and higher frequencies). With the start of the downward drive of the drag-free cart, a mechanical impulse transmits to the floor, due to the suddenly decreased weight of the dropping chamber. The floor rebound transfers vibrations also to the superspring which gets in excitement. This type of disturbance can become dangerous because there might be similar disturbances in every drop (no positive averaging effect). For that reason, a good foundation (concrete pier, rock) is required. E.g., if the concrete is not well consolidated or bound, the instrumental vibration in connection with the floor rebound may cause an offset of some microGal. The only station in Norway where we suppose some problems is the site in **Hønefoss** (Statens Kartverk, left pier, in the middle of the room). On the first view the surface of the pier looks very good. But when we removed our instrument we recognized some small cracks. The second pier (right, close to the wall) shows cracks more obviously. My recommendation is that the operators should choose very carefully the positions of the six feet of the FG5 on the pier. Knocking with a screw driver or a hammer on the surface of the pier may help to decide between good or bad positions. Next time I will pay more attention to the setup position of the meter on the pier.

We did not find any **temperature problems** in the Norwegian stations. In stations in Finland, Sweden and Denmark the conditions were sometimes different. The coldness of the pier or the floor (and their temperature changes over day and night) caused the superspring to drift during the measurements (leaving best operation range). More often, adjustments and alignments were necessary. That will have some impact on the scatter of the drop results, but hopefully no serious influence on the final mean value. For the operators such problems would mean to look more often after the instrument (doing some re-adjustment) and to perform more measurements, e.g., 1000 free-fall experiments more.

Earth tide effects should normally not be a real problem for the absolute gravimetry groups. Measuring round the clock (25 hours (1 day) or 50 hours (2 days)) will ensure that the mean is not affected by not-well modelled half-daily or daily tidal waves of the ocean. In **Trondheim**, the uncertainty of the moving water in the fjord became visible in the single set results distributed over the days (a sinusoidal wave of more than 10 microGal double-amplitude). In one night the water level in the fjord varied between +1 m and -1 m. In addition, the ground water table will strongly be influenced by the fjord water. So, measurements distributed over 12 hours or only performed over 2 or 3 nights would not solve the tidal reduction problem.

Ground-water (and also soil/rock moisture) is still a big problem in absolute gravimetry. If we could measure absolute gravimetry every year under equal ground-water conditions, there would be no influence on the difference between the year results. Or if we see that the water gauge measurements from 5 years (always simultaneously with absolute gravity observations) show a random behaviour around a mean value and no linear trend, we can assume again that the gravimetric result (gravity changes with time) is not influenced by the ground-water movement. All possibilities to monitor the ground-water situation during the absolute gravity observations should be use (water level gauges, levelling to nearby lakes or rivers). Bernt Sovik offered to measure the ground-water level at the station **Ålesund** periodically (every one or two weeks?) which would be an opportunity to learn more about the water in the mountain. He already observes the rain fall. Does the water gauge show mainly the falling rain water with some delay? For absolute gravimetry, **Trysil** seems to be an excellent station with respect to man-made microseisms, site stability, temperature stability and working conditions. But we saw a lot of water around the station and over the whole area which will also vary with time. My suggestion is that we should not only register the water table gauges but also determine more often absolute gravity within one year (e.g., 2 times per year over 5 years). That will result in a better mean value due to averaging. Perhaps the new absolute gravimetry group from Ås can help.

Conclusions for the group from IFE (Univ. Hannover):

- For the progress during a field campaign we should plan at least 5 days instead of 4 days for each station. That will help to avoid unfavourable environmental conditions due to wind, rain fall, etc., during the observations.

- The stations **Ålesund** and **Vagstranda** should be handled as a "double pack". Depending on the weather condition, the absolute gravimetry group can go first to the coastal station or to the inland station which will give more flexibility in the campaign.

- I recommend to support Bernt Sovik with the idea to register periodically the water table depth in **Ålesund** (e.g., over one year every week). To assess our accuracy of the observed gravity changes after 3 or 5 repetitions we need an indicator with respect to the subsurface water problem. In addition, it is a great chance to get more experience with such problems. It is a chance to learn.

- It should be discussed with the group from Prof. Pettersen to occupy the station **Trysil** more frequently within our cooperation (e.g., two times per year over 5 years) due to the ground-water and soil moisture problem.

- From my point of view, the IFE group performed one "weak" absolute gravity determination. It was at the station **Hønefoss** (Statens Kartverk). Whenever we looked through our telescope to check the laser beam reflection from the fluid surface (alcohol pot) the reflection was flickering. In addition, the superspring was never really calm. One source of disturbances was clearly the earthquake induced seismic waves during that time. I am not sure about our instrumental setup. Were the feet of the FG5 placed in the best position on the surface of the pier? I need a detailed discussion with the group from BKG about their experiences. What do their data show (residuals, scatters)? I would appreciate if the group from Ås can help to get more experiences at that station in the next year.

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