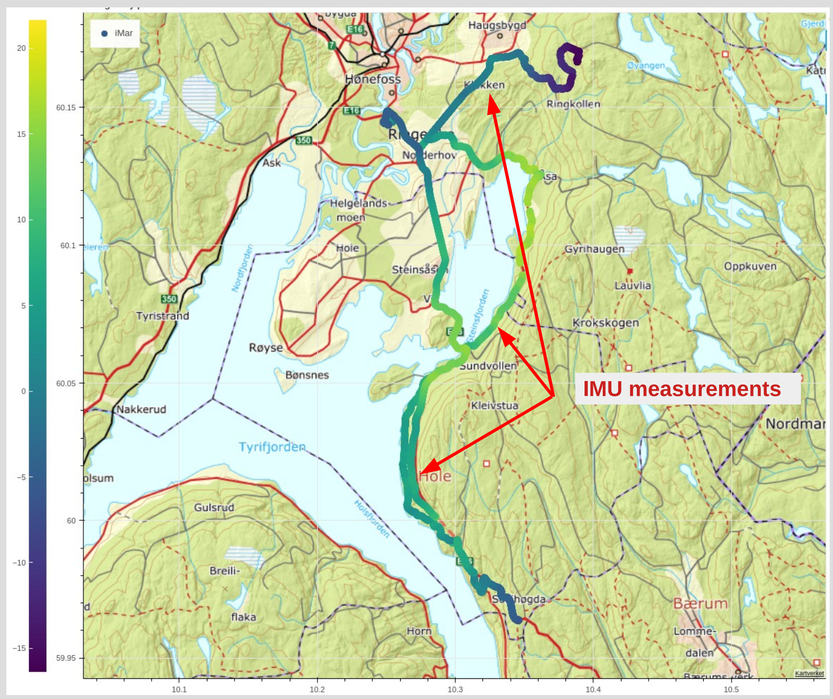
# IMU + a car: continuous relative land gravity measurements?

## Idea

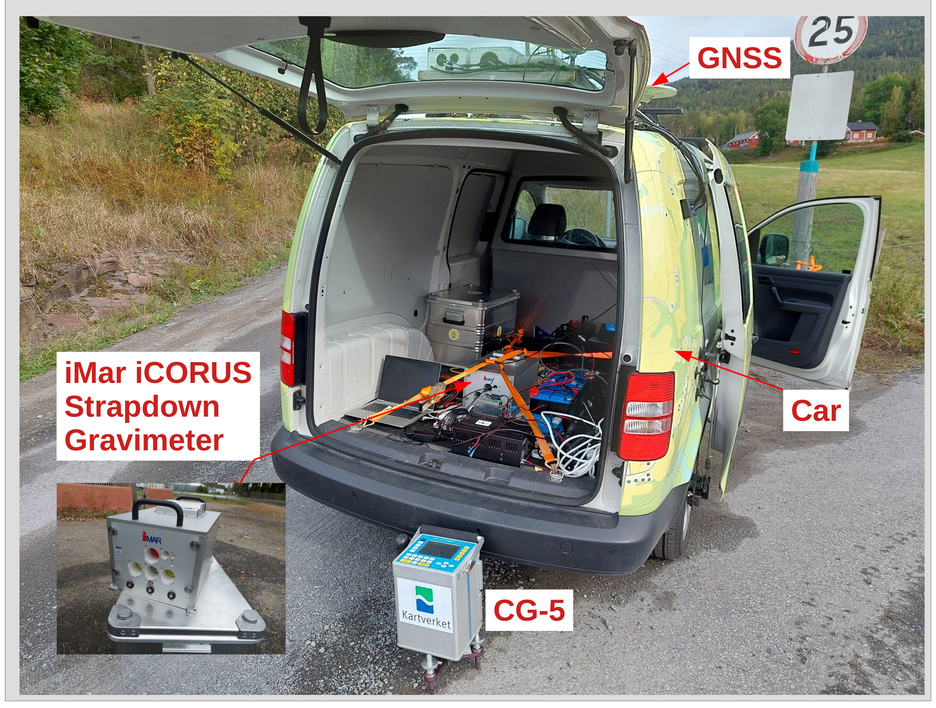
May we substitute time consuming point gravity measurements with continuous IMU gravity measurements?

- How close to “true/correct” gravity do we get?
- What will be lost in filtering?
- Gravity-tie: how far apart?

## Test area around Hønefoss




## Test equipment



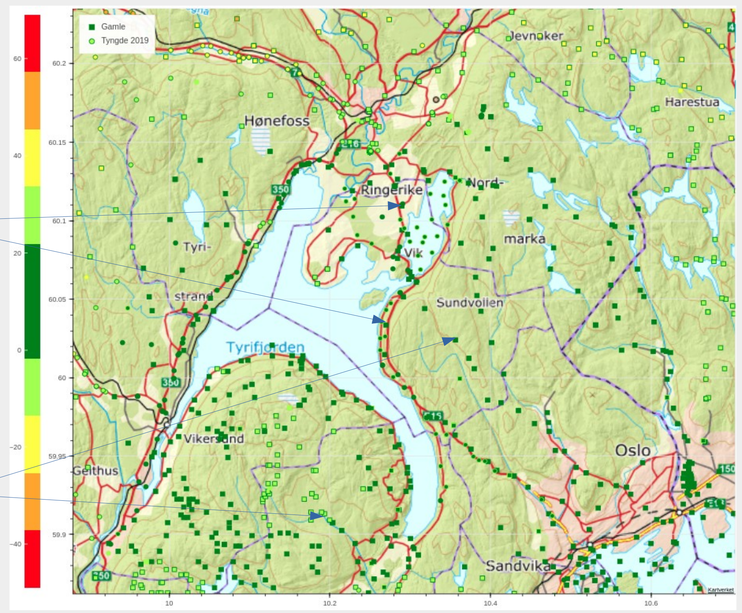

## “True” gravity!!

### CG-5 “true” gravity

- Measured along IMU path; within 20 meters
- 56 CG-5 gravity measurements
- Approx every 2 km

### “True” NKG gravity

- Estimated from NKG gravity database, not including “new” CG-5 gravity measurements
- Estimated at same location as IMU path




## IMU – Inertial Measurement Unit

An inertial measurement unit (IMU) is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the orientation of the body, using a combination of accelerometers, gyroscopes, and sometimes magnetometers. Wikipedia.

## IMU gravity measurements


**GNSS measurements**
- Processed using rtklib
- Reference station @ Hønefoss
- Removes kinematic accelerations

**IMU analysis**
- Processed using iPosCal-GRAV
- Combine GNSS and IMU observations
- CG-5 connection points at start and end

→ **gravity**

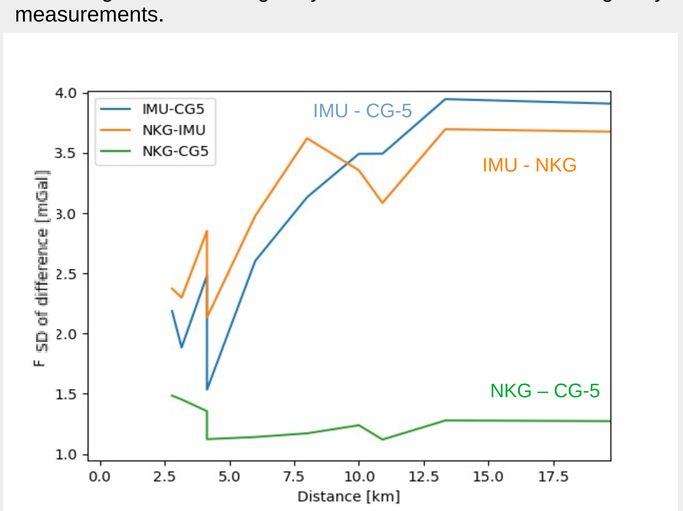
$$g_D = \ddot{h} - f_D + \left( 2\omega_e v_E \cos\phi + \frac{v_N^2 + v_E^2}{R} \right)$$

GPS — IMU — Eötvös correction

## Results

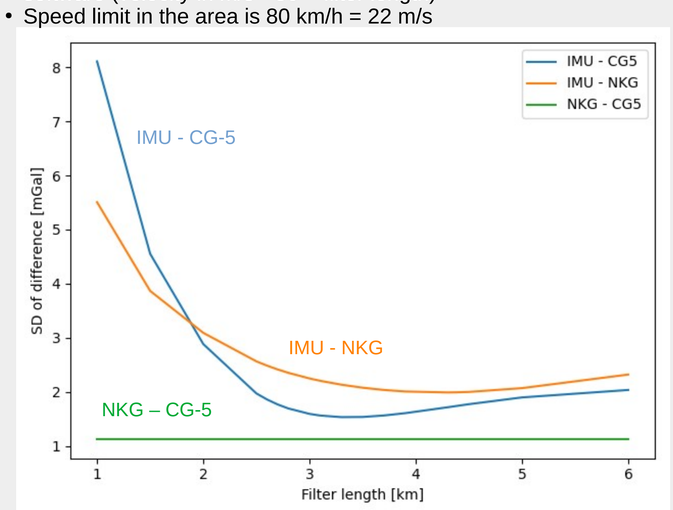
### Distance between connection points

- IMU data is relative gravity data and must be connected to “true” gravity values via CG-5/A10 measurements.
- Connecting only the start and end point we get a fit to the CG-5 control points of approx 4 mGal, decreasing down to 1.5 – 2.0 mGal with the increase in number of connection points.
- The fit also depends on which connection points are selected
- NKG – CG-5: show that we get a better fit to the control points by estimating from the NKG gravity database than from the IMU gravity measurements.




### Filter length

- The IMU measurements are quite noisy when driving the car (kinematic accelerations) and a filter is applied to remove the high frequency signal.
- Figure shows the fit of IMU data to control points give a minimum around 3.3 km. The optimum filter depends slightly on the number of connection points. 29 control points used (approx 4 km apart).
- A 3 km filter indicates a velocity of 60 m/s = 216 km/h according to the software (velocity in m/s * 50 = filter length)
- Speed limit in the area is 80 km/h = 22 m/s

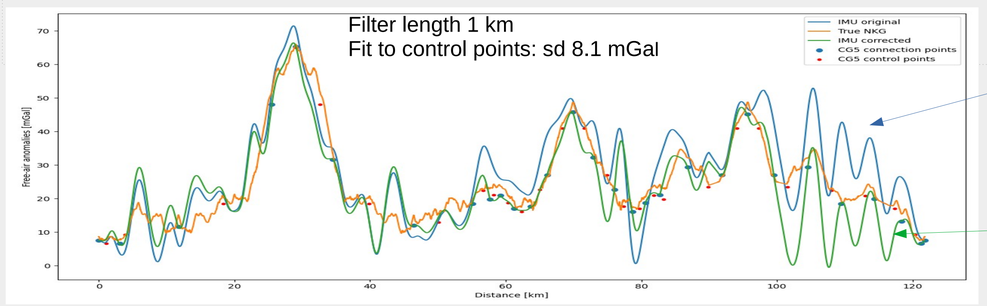


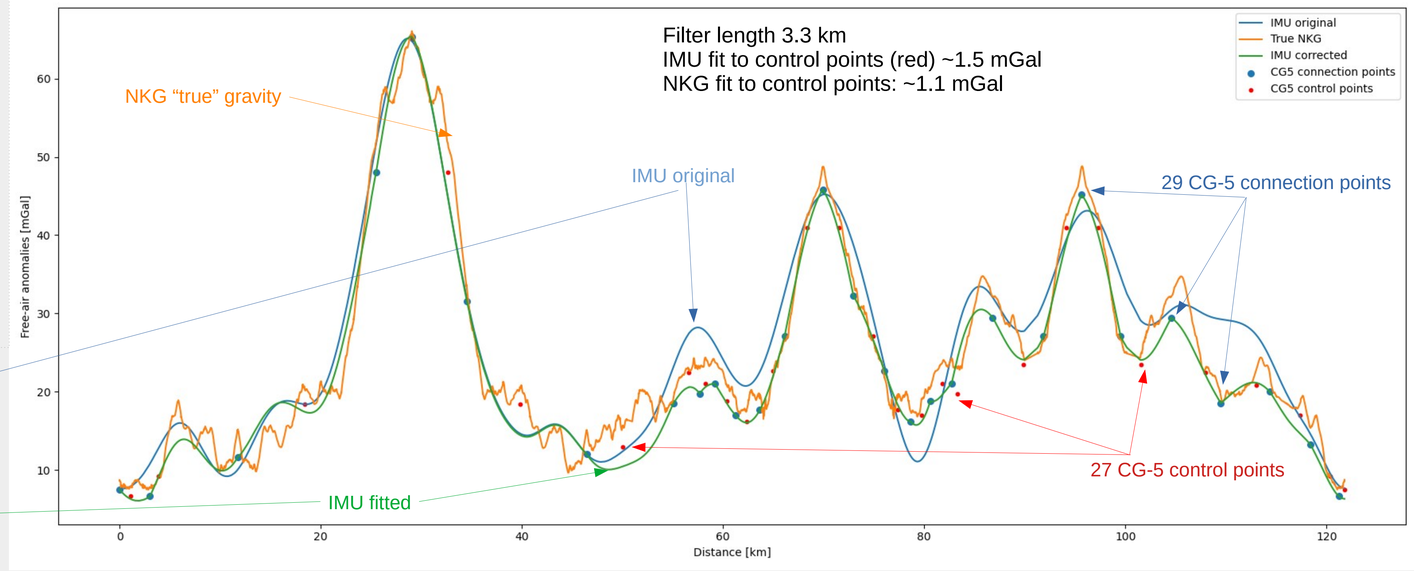

## Conclusions

- IMU fits control points @ ~1.5 – 2.0 mGal
- IMU: no high frequency data due to filtering
- Lever arm:
  - a good estimate is important
  - z-coordinate is difficult to estimate.

## How close to “true” gravity is IMU?

- The fit to the CG-5 control points depends on the selected filter length, number of connection points and a good estimate of the lever arm.
  - Figure below has filter length of 1 km, 29 connection points and 27 control points give a fit of 8.1 mGal,
  - Figure to the right: a filter length of 3.3 km gives a fit of 1.5 mGal.
- A strong filter is applied to the IMU data, so, naturally, the high frequency gravity signal will be missing.




Kartverket

**Digital copy of my poster!**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NKG General Assembly, Copenhagen, September 2022


Norwegian Mapping Authority