DETERMINATION OF THE GRAVITY FIELD OVER NORWEGIAN TERRITORIES

POSITIONING DATA – FOR SOCIETY’S BENEFIT
Determination of the GRAVity field over NORwegian territories using GOCE data and space geodesy software GEOSAT

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SPACE GEODESY SOFTWARE GEOSAT

- 25 years at Norwegian Defence Research Establishment
- GPS, VLBI, SLR simultaneously at observation level
  - Inter technique calibration
- Stochastic parameter evolution between days (arcs)
  - Utilization of parameter statistics
- Accelerometry: GOCE
GOCE (Gravity and Ocean Circulation Explorer)

- Altitude: 250 km
- 6 accelerometers on board
- Not placed in Center of Mass: Gravity signal
- Frequency range of accelerometers: 5-100 mHz
- Ground track spatial resolution: 100-1500 km
DETERMINATION OF LOCAL GRAVITY (NORWAY)

- Norwegian Mapping Authority (NMA):
  - Contribute to the determination of climate parameters
  - Determine the cm geoid
  - Transfer of GEOSAT competence from NDRE to NMA

- Why local analysis?
  - ESA -> SH expansion: truncation issues (40,000 parameters)
  - May still be information left in accelerometer signal
  - Norway gravitationally “rough”
STRATEGY

POSITIONING DATA – FOR SOCIETY'S BENEFIT
SINGLE ACCELEROMETER OBSERVATIONS

Benefits:
- Less susceptible to accelerometer failure
- Algorithms applicable to other missions like GRACE

Disadvantage:
- Non-gravitational force has to be modeled as part of gravity field determination
ACCELEROMETER OBSERVATION EQUATION

Output of accelerometer j:

\[ A_j = M_j a_j + Q_j (\tilde{A}_j)^2 + B_j + \dot{B}_j \Delta t + (\text{Fourier})_j \]

\[ \tilde{A}_j = M_j^{-1} \left[ \tilde{A}_j - B_j - \dot{B}_j \Delta t - (\text{Fourier})_j \right] \]

True acceleration:

\[ a_j = \left( R - \Omega^t TV^2 VT^t \Omega \right) (L_j + O) + \Omega^t D + \ddot{\Omega} \]
ATTITUDE CORRECTIONS

GRF 2 CRF rotation matrix:

\[ \Omega(q) = R_3(\phi_3)R_2(\phi_2)R_1(\phi_1)\Omega(\tilde{\phi}) \]

\[ \phi_i = B_\phi(i) + C_\phi(i) \cos u + S_\phi(i) \sin u \]

Indirect effect on true acceleration:

\[ R(\bar{\omega}, \dot{\bar{\omega}}) \]

\[ \omega_{x_i} = \frac{1}{2} \sum_{j,k=1}^{3} \epsilon_{ijk} \hat{\Omega}_{lj} \Omega_{lk} \]
DYNAMIC ORBIT DETERMINATION/CALIBRATION

Computation of orbit:

\[ \ddot{\bar{r}} = T \nabla V + \hat{D} + \Delta \]

\[ \bar{r} = \bar{r} \left[ \bar{r}_0, \hat{D}(M_i, B_i, \phi_i, ...), ... \right] \]

Accelerometer orbit-□GPS orbit=instrument imperfections□

Expression for non-gravitational force D dependent instrument imperfections?
Estimate of D for Dynamic Orbit Determination

LSQ applied to accelerometer observations with D as only unknown:

\[
\hat{D} = \Omega \left( \sum_{i=1}^{6} M_i^t W_i M_i \right)^{-1} \times \\
\sum_{j=1}^{6} M_j^t W_j \left[ \tilde{A}_j - A_j(D \equiv 0) \right]
\]
CALIBRATION BY DOD

- **Issue**: Along-track scale factor not well determined from DOD alone due to along-track DFC (Visser, 2009)

- **Solution**: Simultaneous determination of orbit and local gravity field
PARALLELL AND FUTURE

- Altimetry: Sea level & ocean currents
- IVS Analysis Centre
- GRACE
- COMMENTS □?