Impact of temporal gravity field parameters determined from GNSS satellites on the estimated Earth rotation parameters

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IGS Workshop 2014 – Celebrating 20 Years of Service
June 23–27 2014, Pasadena, California, USA
Introduction:
- Motivation
- GNSS sensitivity to low-degree Earth’s gravity field coefficients
- Solution set-up

Temporal Earth’s gravity field from GNSS
- $C_{20}$ and correlation with dynamical orbit parameters
- Other low-degree coefficients

Earth Rotation Parameters (ERPs) & Geocenter
- Pole coordinates
- Pole rates
- Geocenter coordinates

Conclusions
Three pillars of satellite geodesy

Current status:
IGS provides products related to Geometry and Rotation, but not to temporal variations in the Earth’s Gravity field.

This solution:
Parameters related to all three pillars are simultaneously estimated, because they are strongly dependent on each other.

Are GNSS satellites sufficiently sensitive to variations of gravity?
Sensitivity of GNSS solutions to low-degree gravity coeff.

Mean a posteriori errors – monthly solutions

R: resonant coefficients causing “secular drifts” of GPS semi-major axes

GNSS satellites are very sensitive to gravity field coefficients of degree 2. For coefficients above degree 3, GNSS are typically very sensitive only to resonant gravity field coefficients.

GRACE
multi-SLR
CHAMP
GPS+GLONASS
**List of estimated parameters & solution set-up**

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<th>Estimated parameters</th>
<th>GNSS solutions</th>
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<td>up to 32 GPS and 24 GLONASS satellites</td>
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<td>a, e, i, Ω, ω, u₀ (1 set per 3 days)</td>
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<td>Station coordinates</td>
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<td>Other parameters</td>
<td>Troposphere ZD (2h), gradients (24h) and ZTD biases</td>
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We processed **10 years of GPS and GLONASS** data using the standard orbit modeling as from CODE with **two major exceptions**:

- **7-day solutions** are generated instead of the 3-day long-arc solutions as for the IGS.
- The Earth's **gravity field coefficients** up to degree/order 4/4 and **geocenter** coordinates are simultaneously estimated along with other parameters.
**C_{20} from GPS+GLONASS**

**Offset between SLR and GNSS↓**

**Semiannual signal is not recovered ↓**

**GNSS dynamic orbit parameters**: \( D_0, Y_0, X_0, X_S, X_C \)

**Orbit parameters in the X direction are correlated with **C_{20}**

**Offset is reduced ↓**

**Semiannual signal is recovered ↓**

**GNSS dynamic orbit parameters**: \( D_0, Y_0, X_0, X_S, X_C \)
GNSS–derived gravity field parameters agree quite well with the CSR RL05 results (median difference of $8.2 \times 10^{-11}$), but:

- GNSS–derived parameters show both: the seasonal signals as well as draconitic periods,
- $C_{20}$ is correlated with orbit parameters in the $X$ direction.

Gravity coefficients benefit from the contribution of GLONASS (after 2008, when the station coverage improves).

**C$_{21}$, S$_{21}$, C$_{30}$ from GPS+GLONASS**

![Graphs](image)
Question:

How much affected are the GNSS–derived parameters by neglecting the temporal gravity field variations, since GNSS satellites are sufficiently sensitive to recover the temporal variations of Earth’s low–degree gravity field?
For the X pole coordinate:

- the amplitude of the 7th harmonic is reduced from 15.9 to 12.2 µas,
- the amplitude of the annual signal is reduced from 12.8 to 6.9 µas,
- the mean offset w.r.t. IERS–08–C04 is reduced from –10.5 to –9.9 µas,

for the solutions without and with estimating gravity field parameters, respectively.
For the X pole rate:
- the amplitude of the 7th harmonic is reduced from 3.5 to 1.8 μas/day,
- the mean offset w.r.t. IERS–08–C04 is reduced from 2.2 to 2.0 μas/day,
for the solutions without and with estimating gravity field parameters, respectively.
Z component of geocenter coordinates \((C_{10})\)

When estimating the gravity field coefficients and heavily constraining once-per-revolution orbit parameters in the X direction, the Z geocenter coordinate from GNSS solutions \((C_{10})\):

- is by far less affected by solar radiation pressure modeling,
- is closer to the SLR results as compared to GNSS solutions without estimating gravity field.
Summary

The GNSS satellites are sufficiently sensitive to low-degree gravity field parameters, to recover the temporal gravity field variations.

The simultaneous estimation of gravity field parameters along with ERPs, station coordinates, troposphere, and other GNSS parameters is feasible.

The empirical orbit parameters in the X direction are correlated with $C_{20}$, and thus, the X-parameters partly absorb the $C_{20}$ variations. However, not all the gravity variations are absorbed by empirical parameters.

Unabsorbed gravity variations may contaminate the ERP estimates by introducing spurious peaks of seasonal and draconitic signals in the GNSS solutions when not estimating gravity field parameters.

Spurious seasonal and draconitic signals can be reduced by estimating the gravity field along with other GNSS parameters.
Thank you for your attention