Earth gravity field recovery using GPS, GLONASS, and SLR satellites

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Time-variable Earth’s gravity field can be determined from:

- K-Band GRACE observations,
- GPS-derived positions of LEO satellites (e.g., CHAMP),
- Orbit perturbations:
  - using SLR to geodetic satellites,
  - using GPS and GLONASS microwave observations
GNSS satellites are very sensitive to gravity field coefficients of degree 2. For coefficients above degree 3, GNSS are only sensitive to resonant gravity field parameters (®).
GNSS solutions are similar to the standard IGS solutions provided by CODE (Center for Orbit Determination in Europe), with some exceptions: Earth gravity field parameters are simultaneously estimated and 7–day instead of 1–day solutions are generated. SLR solutions are similar to the standard ILRS solutions provided by BKG, but more satellites are included (Sta/Ste/Aji) and Earth gravity field parameters are estimated.
GPS + GLONASS solutions
GNSS orbit modeling

**GNSS dynamic orbit parameters estimated in standard CODE solutions:**

- \( D = D_0 \)
- \( Y = Y_0 \)
- \( X = X_0 + X_s \sin \Delta u + X_c \cos \Delta u \)
C\textsubscript{20} from GPS and GLONASS

**GNSS dynamic orbit parameters**: \(D_0, Y_0, X_0, X_s, X_c\)

The constant and once-per-rev parameters in \(X\) are correlated with \(C_{20}\)

**GNSS dynamic orbit parameters**: \(D_0, Y_0\) (no parameters in \(X\))

These issues need further investigations.
Zonal spherical harmonics from GPS and GLONASS

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3rd harmonic

7th harmonic

Annual signal shifted towards draconitic years

Semiannual signal is well recovered

Zonal harmonics can be recovered by GNSS to some extent
Resonant GPS harmonics

Resonant harmonics, despite a large sensitivity, cannot be fully recovered by GNSS, because of the correlations with $D_0$. 
SLR solutions
Some coefficients derived by SLR, CHAMP, and GRACE solutions agree very well. CHAMP solutions show typically larger amplitudes.
SLR vs. CHAMP vs. GRACE

Amplitudes of annual signals of low gravity field coefficients (x1e-10)

15 out of 21 (71%) coefficients up to d/o 4/4 are derived from SLR with a quality similar to GRACE's.

13 out of 21 (62%) coefficients up to d/o 4/4 are derived from CHAMP with a qual. similar to GRACE’s.
Sośnica et al.: Earth gravity field recovery using GPS, GLONASS, and SLR satellites. 18th International Workshop on Laser Ranging, Fujiyoshida, Japan

C\textsubscript{41} derived by SLR shows similar secular trend to the GRACE results, but the high-frequency part is affected by correlations and modeling deficiencies.
Deficiencies in S2 tide (from the background models) affect not only the GRACE solutions, but also have a minor impact on the SLR solutions.
Low-degree geoid variations [mm]

AIUB-SLR, December 2004
up to d/o 4/4, no filtering

AIUB-GNSS, December 2004
up to d/o 4/4, no filtering

AIUB-GRACE, December 2004
up to d/o 60/45, 1000km Gauss filter

AIUB-CHAMP, December 2004
up to d/o 60/60, 1000km Gauss filter

Low-degree gravity field parameters from SLR solutions fit well to the GRACE results.
Summary

- The gravity field determination using GPS+GLONASS data is very promising, but requires further investigations.

- Most of the low-degree coefficients can be very well established by the observations of SLR geodetic satellites,

- Small issues related to SLR-derived gravity field coefficients originate from:
  - Deficiencies in background models, which are reflected, e.g., in the $S_2$ alias tide,
  - Deficiencies in the modeling of non-gravitational forces (solar radiation pressure, albedo, the Yarkovsky and Yarkovsky–Schach effects),
  - Correlations between gravity field parameters (e.g., $C_{30}$ and $C_{50}$) and other parameters (e.g., orbits: perigee, ascending node, etc.).
Thank you for your attention
Geocenter coordinates from GNSS and SLR

Z geocenter component from GNSS is extremely sensitive to orbit modeling; the exclusion of dynamic orbit parameters in the X direction entirely changes the signal!
Geocenter coordinates from GNSS and SLR

- **Geocenter – X**
  - [Graph showing time series data for Geocenter – X]
  - Labelled with: GNSS – CODE, GNSS – no $X_p$, $X_s$, $X_C$, LAGEOS-1/2

- **Spectrum of Geocenter – X**
  - [Graph showing spectral analysis for Geocenter – X]

- **Geocenter – Y**
  - [Graph showing time series data for Geocenter – Y]

- **Spectrum of Geocenter – Y**
  - [Graph showing spectral analysis for Geocenter – Y]
References

References:

- Sošnica K, Thaller D, Dach R, Jäggi A, Beutler G (2013c) Time variable Earth’s gravity field from SLR and the comparison with polar motion, CHAMP, and GRACE results. To be submitted to J Geod