GOCE Gravity fields established by the Celestial Mechanics Approach

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G4.2: Satellite Gravimetry: GRACE, GOCE and Future Gravity Missions

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What do we show?

- GOCE gravity fields computed from 8 months of data with the Celestial Mechanics Approach (CMA)
  - GPS ($l_{\text{max}}=120$)
  - Gradiometer: XX, YY, ZZ ($l_{\text{max}}=160$)
- Combination with 7 years of GRACE (CMA)
- First results with reprocessed gradiometer and attitude data (84 d, $l_{\text{max}}=200$)
Why do we show it?

- Independent gravity field solution
- New concept to deal with gradiometer noise (no a priori knowledge on noise–PSD necessary)
- Consistent combination with GRACE
- Proof of concept: \( l_{\text{max}} = 160 \)
- Final solution: \( l_{\text{max}} = 200 \) (currently limited by computing resources)
- Fair weight of GPS–part (\( l_{\text{max}} = 160 \))
Specialties of the CMA (applied to gradiometry)

Constrained Piecewise Linear Parameters (PWL) absorb signal below measurement bandwidth of gradiometer.

Constraints on 2\textsuperscript{nd} derivatives of PWL allow for:

- “hard” constraints: resampling
- “soft” constraints: smoothing
Results from 2 months of data.

smoothed 1 min PWLs

\( \cong \)

empirical covariances
Gradiometer–only solutions

- more data => better gravity field (quality dominated by noise, not yet by background model error)
- omission error ($l_{\text{max}} = 160$)
- improvement at low degrees (reprocessed data)
GPS–only solutions

- few months of GOCE comparable to 8 years of CHAMP
- more CHAMP data
- lower GOCE orbit
- omission error ($l_{\text{max}}=120$)
Gradiometer + GPS

- omission error of GPS degrades gradiometer solution (rel. weights according to ratio of RMS)
- increasing $l_{\text{max}}$ (GPS) cures the problem
Formal Errors

- relative weighting: ratio of RMS (GPS down-weighted)
- formal errors of low degrees too optimistic (GRACE), otherwise good agreement.
GRACE + GOCE

- more data => better solution
- omission error at $l_{\text{max}} = 160$
A closer look

GOCE helps:
- improve sensitivity
- reduce GRACE aliasing errors on resonant orders

Reference: GOCO02S
Comparison to other solutions

- $\sqrt{3}$-gain for GPS (energy-approach in TIM is only 1D)
- a priori information in DIR
- TIM is part of GOCO02S
- omission error
### External validation

<table>
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<tr>
<th>Reference</th>
<th>n</th>
<th>CMA</th>
<th>DIR–2</th>
<th>TIM–2</th>
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<td>BRD GPS-benchmark</td>
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</tbody>
</table>

All gravity fields truncated at degree 155.

Validation performed by Thomas Gruber (only high-quality data sets shown).
Comparison to EGM2008 and GOCO02S

Gravity anomalies
($l_{\text{max}} = 155$)

Anomaly south of Australia

Diff. to EGM2008 (155)
WRMS (global): 1.39 mGal
WRMS (oceans): 0.60 mGal

Diff. to GOCO02S (155)
WRMS (global): 0.31 mGal
WRMS (oceans): 0.33 mGal
Summary and Outlook

- CMA is a powerful tool for satellite gravity gradiometry, as well.
- To avoid artifacts GPS has to be taken into account to $l_{\text{max}} > 120$ (or must be downweighted).
- GOCE contribution cures aliasing artifacts on resonant orders of GRACE.
- The CMA–derived gravity fields are currently expanded to even higher degrees (200).