High-resolution grids of GOCE-only gravitational gradients for geophysics

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5th INTERNATIONAL GOCE USER WORKSHOP
http://www.goce2014.org/

25-28 November, 2014
Motivation & Background

Summary of the approach applied

TRF data
- STEP 1
- STEP 2
- Results at satellite altitude
- High degrees in TIM-r5 and DIR-r5
- Results at lower altitude

Products summary

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- Working on GRACE/GOCE data regionally within STSE ⇒ why not globally?
- GOCE data: GRF and TRF GGs, geopotential models (combi. & only), grids (combi. by DGFI+UWB) ⇒ no GOCE-only grids (SPW grids?)?
- 2 (Dirichlet-problem) siblings: spherical harmonics and Poisson integral equation ⇒ should provide equal results
- ⇒ Feedback on TRF data.
- Useful or not? ⇒ users will answer.
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On the approach applied

**Input:** GOCE L2 TRF gradients for 2009-2013 (Oct19)

1. Real orbit $\rightarrow$ mean orbital sphere (MOS) - **Gradient approach**
   - A priori model used for $\frac{dV_{ij}}{dr}$ (TIMr4)
   - GOCE data position varies $\pm$ 15/30 km (before/after descends in 2012-13)
   - On a constant sphere gridding is “easy” (number of software)

2. MOS $\rightarrow$ downward - **Iterative approach equipped with Poisson integral equation**
   - No a priori gravity information (starts with given data)
   - Iterative approach according to Landweber (1951)
   - The approach provides error estimate in the spatial domain $\Rightarrow$ wash your data!

**Output:** 10 arc-min “noise-free” GOCE-only grids at MOS and MOS-234 km, noise estimates
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Note on L2 TRF data

See GOCE L2 Product Data Handbook (p. 49):

“The EGG_TRF_2_ gravity gradients should be used for local applications. Because of the use of (external) gravity field models to compute the long wavelength part of these gravity gradients, they should not be used for global gravity field analysis. Or at least the results from such an analysis should be interpreted with care.”

⇒ applies also to our GOCE-only grids!
STEP 1 - ro2mos

Nominal accuracy of gradient mapping: RMS=0.01 mE
STEP 2 - mos2down

- Integral equation: \[ V(\mathbf{r}) = \frac{R(r^2 - R^2)}{4\pi} \int_{\lambda=0}^{2\pi} \int_{\theta=0}^{\pi} \frac{1}{l^3} V(\mathbf{R}) \sin \theta' \, d\theta' \, d\lambda \]
- Algorithm: \[ \mathbf{f}_i = \mathbf{f}_{i-1} + p \cdot (\mathbf{g} - \mathbf{K} \cdot \mathbf{f}_{i-1}) \text{ with } \mathbf{f}_1 = \mathbf{g} + p \cdot (\mathbf{g} - \mathbf{K} \cdot \mathbf{g}) \]
Results at satellite altitude

$T_{xx}$
Results at satellite altitude

Txy
Results at satellite altitude

$T_{xz}$
Results at satellite altitude

Tyy
Results at satellite altitude

Tyz
Results at satellite altitude

$T_{zz}$
Results at satellite altitude

Laplacian before washing
Results at satellite altitude

Noise estimate from iteration

[Map showing noise in Tzz with RMS value of 3.7 mE]
Results at satellite altitude

$T_{zz}$ difference with EGM2008 (300) with noise
Results at satellite altitude

$T_{zz}$ difference with EGM2008 (300) w/o noise
Results at satellite altitude

$T_{zz}$ difference with TIM-r5 (280) w/o noise (0.4 mE for TIMr3 before repro, R. Pail)
Results at satellite altitude

Degree variance with noise (before washing)
Results at satellite altitude

Degree variance without noise (after washing)

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Graph showing degree variance for different models (GRINGO, TIMr5, GRINGO-TIMr5) at satellite altitude.
High degrees in TIM-r5 and DIR-r5

<table>
<thead>
<tr>
<th>Difference</th>
<th>$T_{22}^z$ (MOS) in mE</th>
<th>$T_{22}^z$ (MOS-234 km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIMr5(280) - TIMr5(220)</td>
<td>0.262 mE</td>
<td>1.447 E</td>
</tr>
<tr>
<td>DIRr5(280) - DIRr5(220)</td>
<td>0.263 mE</td>
<td>1.462 E</td>
</tr>
<tr>
<td>DIRr5(220) - TIMr5(220)</td>
<td>0.337 mE</td>
<td>0.151 E</td>
</tr>
<tr>
<td>DIRr5(280) - TIMr5(280)</td>
<td>0.342 mE</td>
<td>0.531 E</td>
</tr>
</tbody>
</table>

The same proportions for other components!

- You can see the same in GPS levelling by T. Gruber.
- **Let’s see that in the spatial domain** ⇒
Sample results at lower altitude

Tzz at MOS-234 km

Tzz: DIRt5 220, [E]

Tzz: TIMr5 220, [E]

Tzz: Continued field, [E]

Tzz: DIRt5 280, [E]

Tzz: TIMr5 280, [E]

Tzz: EGM2008 280, [E]
Sample results at lower altitude

Tyy at MOS-234 km

Tyy: DIRr5 220, [E]

Tyy: TImr5 220, [E]

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Tyy: DIRr5 280, [E]

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Tyy: EGM2008 280, [E]
Sample results at lower altitude

Txx at MOS-234 km

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Txx: Continued field, [E]

Txx: DIRr5 280, [E]

Txx: TIMr5 280, [E]

Txx: EGM2008 280, [E]
Products summary (including “the kitchen”)

- **@ MOS (satellite altitude)**
  - GGs along the orbit but on the MOS
  - GGs grids with noise (after interpolation)
  - GGs grids with reduced noise (after washing)
  - GGs from latest models up to d/o 220 and full resolution

- **@ MOS-234 km (above the ground ... including “the roof”)**
  - DC GGs grids with reduced noise (after washing and continuation)
  - GGs from latest models up to d/o 220 and full resolution

- **Software** - Matlab script that will do (regional) downward continuation - work with GGs @ MOS on your own!

GOCE L2 Product Data Handbook: “The EGG_TRF_2_ gravity gradients should be used for local applications. Because of the use of (external) gravity field models to compute the long wavelength part of these gravity gradients, they should not be used for global gravity field analysis. Or at least the results from such an analysis should be interpreted with care.”
Summary

• Washing ongoing! ⇒ wait for Xmas.
• GOCE-only 10 arc-min grids from L2 TRF GGs possible
• Models and grids consistent at sat. altitude (0.6 mE for $T_{zz}$)
• L-w effects in $yy, yz, zz$ identified (L2 TRF?).
• Make it “easy” in application: use multiple models (TIM, DIR, GOCO, ...) and multiple grids (DGFI, ours)
• With models near the ground, carefully with a maximum degree - realistic DV vs. realistic spatial maps

http://goce.kma.zcu.cz
Thank You

ESA