Recent Mascon Solutions from GRACE

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The VI Hotine-Marussi Symposium
Wuhan, China
Overview

• GRACE gravity validation solutions

• Harmonic solution

• Mascon (mass concentration) solution

• Comparisons of harmonic and mascon solutions

• Summary

• Future works
JPL GRACE Gravity Validation Solution

• KBR1B, GPS1B, ACC1B, SCA1B, and AOD1B from GRACE Level-1 products.

• Validation solutions Jan 2003 - Dec 2005:
  – Release 2 harmonic solutions using AOD RL01 and RL03 (PPHA and OMCT based ocean models)
  – JPL release 2 parameterization proven effective, harmonic solutions are demonstrated state-of-the-art

• Mascon solutions using AOD RL01 (PPHA-based)
  – Several variants (area dimension, correlation, etc)
Background Model Improvement

• Nominal gravity model - GGM02C to degree 180

• IERS 2003
  – J2-dot, C21/S21-dot
  – solid earth tide
  – solid earth pole tide

• Ocean tide using convolution formalism with weights derived from FES04 model to degree 60 (Desai)

• Ocean pole tide SCEQ (Desai) model to 30x30
Harmonic Solution

• FLINN GPS ephemeris and clock solution

• Parameterization for GRACE orbit determination
  – Daily ACC biases
  – KBR empirical biases every orbital revolution
  – Stochastic GPS transmitter clock & GPS-GRACE phase biases

• Estimated gravity harmonics
  – 120x120 harmonic partials from KBRR data
  – 90x90 harmonic partials from GPS data.
JPL Mascon Model Implementation

• Mascon models in MIRAGE software
  – Point mass, flat disk, spherical cap and spherical ring
  – Equal area or variable area (with latitude)
  – Compute direct gravity acceleration from mascons, no truncation from any conversion to harmonics

• Same dynamic models, parameterization, and reference orbit for GRACE as our harmonic solution.

• Simultaneous solution for all mascon regions
  – Use both GPS and KBRR data for solution
Advantages of Mascon Basis vs. Spherical Harmonic Basis Functions

- The mass concentration solution is localized in both time and space.
  - Weakens correlations between regional solutions
    - Less “leakage” and propagation of long period errors
- The application of spatial constraints are easier to implement than with spherical harmonics
- Potentially higher temporal and spatial resolution than harmonic solution
  - Make use of actual groundtracks over each mascon rather than limited by equatorial ground track spacing
Mascon Solution

- Estimated globally distributed $4^\circ \times 4^\circ$ equal-area spherical cap mascons

- Optionally apply a spatial correlation of the form:
  \[ e^{-\left(\frac{d_{ij}}{D}\right)} \]
  
  $d_{ij}$ is the angular distance between mascon $i$ and $j$; 
  $D$ is the correlation distance
Distribution of Equal Area Spherical Caps
Post-processing of Harmonic and Mascon Solutions in Surface Water Variations

- Gaussian spectral smoothing with a spherical cap applied to harmonic solutions (Swenson and Wahr, 2002).

\[
\Delta H_{\text{water}}(\phi, \lambda) = \frac{2\pi a}{3} \bar{\rho}_{\text{earth}} \sum_{\ell=0}^{\infty} \sum_{m=0}^{\ell} \frac{2\ell+1}{1+K_{\ell}} W_{\ell} \bar{\rho}_{\ell m} (\sin \phi) \cdot \\
\left[ \Delta C_{\ell m} \cos m\lambda + \Delta S_{\ell m} \sin m\lambda \right]
\]

- Gaussian discrete smoothing with a spherical cap applied to mascon solutions (Jekeli, 1981).
Africa (04/01-04/12)
Smoothed to 600km
Harmonics

Mascons
Africa (05/01-05/12) Smoothed to 600km Harmonics
Amazon (04/01-04/12) Smoothed to 600km Harmonics Mascons
Amazon (05/01-05/12)
Smoothed to 600km Harmonics

Mascons
Arctic (04/01-04/12)
Smoothed to 600km
Harmonics
Mascons
Arctic (05/01-05/12)
Smoothened to 600km
Harmonics
Mascons
Con. US (04/01-04/12)  Smoothed to 600km

Harmonics

Mascons
Con. US (05/01-05/12)
Smoothed to 600km

Harmonics

Mascons
South Asia (04/01-04/12)
Smoothed to 600km
Harmonics
Mascons
South Asia (05/01-05/12)
Smoothed to 600km Harmonics

Mascons
Asia, Mascon (04/01-05/12)
Smoothed to 600km
Europe, Mascon (04/01-05/12)
Smoothed to 600km
North America, Mascon (04/01-05/12)
Smoothed to 600km
Surface Water Variations from Mascons

030101_030131
Summary-1


• Mascon solutions computed for entire globe of Earth with several variants from Jan. 2003 through Dec. 2005 –Automated scripts developed, “pipeline” now in place

• Solutions generally consistent with harmonics for large features but appear able to resolve and localize smaller features more cleanly
Summary-2

• The series of monthly mascon solutions show the same annual patterns as the monthly harmonic solutions with higher resolution and amplitude.

• Although mascons are technically 30+ years old, gravity/geodesy community has vastly more experience with harmonics and thus we are still learning the full advantages, limitations, and idiosyncrasies of mascons
Future Works

• Comparisons with hydrology models & in-situ data will be used for selection of solution strategy in general.

• Mascon solution strategies
  • Submonthly intervals
  • Correlation between regional mascon solutions
  • Sensitivity to the modeling errors
Background Material

\[ \Delta H_{water}(\phi, \lambda) = \frac{2\pi a_e}{3} \bar{\rho}_{\text{earth}} \sum_{\ell=0}^{\infty} \sum_{m=0}^{\ell} \frac{2\ell+1}{1+K_\ell} W_\ell \bar{\rho}_{\ell m}(\sin \phi) \cdot \left( \Delta \bar{C}_{\ell m} \cos m\lambda + \Delta \bar{S}_{\ell m} \sin m\lambda \right) \]

- \( W_\ell \) = Gaussian smoothing factor
- \( K_\ell \) = Load Love number
- \( \bar{\rho}_{\ell m} \) = Normalized Legendre Function
- \( \bar{\rho}_{\text{earth}} \) = Mean density of Earth
- \( \rho_{\text{water}} \) = Density of water

\[ \Delta \bar{C}_{\ell m} = \bar{C}_{\ell m, \text{monthly}} - \bar{C}_{\ell m, \text{mean}} \]
\[ \Delta \bar{S}_{\ell m} = \bar{S}_{\ell m, \text{monthly}} - \bar{S}_{\ell m, \text{mean}} \]

(Swenson and Wahr, 2002)
Surface Water Variations from Harmonics

040101_040113

[Map showing surface water variations with a color gradient indicating meter measurements]