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Isolation of gravity signatures due to major earthquakes from Satellite Gravity Data

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Summary

Satellite gravity (GRACE Satellite) have helped infer near surface fluid exchanges and budgets on a global scale. However, isolating weak gravity signatures due to major earthquakes from satellite gravity is a difficult task as other time-varying fluid exchange signals mask them. Our differential data analysis (Spherical harmonics) attended by spectral filtering has successfully isolated weak gravity signals for three major earthquakes. For illustration purpose we include Sumatra earthquake. Our isolated gravity signals could easily identify the rupture zone in the source region. Both prediction of earthquake occurrence and seismological and gravity modeling of satellite gravity derived gravity signals are underway. These efforts if successful could be a huge step in predicting earthquakes.

***Keywords**: Satellite gravity, Spherical Harmonic Analysis, Differential gravity, Earthquake prediction*

Introduction

Earlier studies of isolation of gravity signatures in satellite gravity for earthquake inference are very limited. Our novel approach is based on differential satellite gravity data. The analysis includes Spherical Harmonics. A brief outline of Spherical Harmonics is provided below:

Spherical Harmonics

The Earth's gravitational potential is given by the Laplace's equation.

- Solving Laplace's equation in spherical coordinates gives us the following equation:

$$V(r,\theta,\phi) = V_o \sum_{n=0}^{\infty} \left(\frac{R}{r}\right)^{n+1} \sum_{m=0}^{\infty} P_{nm}(\cos\theta) \times [C_{nm}\cos(m\phi) + S_{nm}\sin(m\phi)]$$

V is the gravitation potential at (r,θ,φ)
V_o is the mean gravitation potential
r is the distance from the center of the earth
θ, φ are the latitude and longitude respectively
R is the mean radius of the Earth
P_{nm} are the normalized Legendre polynomial
n,m are degree and order associated with Legendre polynomials

- The associated Legendre polynomials are calculated using recurrence relations.

The temporal variations in geopotential are included below:

Temporal Variation in Geopotential

- The geopotential at a particular location on earth varies with time and depends on:

  -Groundwater movement
  -Mass balance of polar ice sheets
  -Mountain glaciers mass balance
  -Tectonic activities and plate movements

- While the first three are gradual seasonal variations, events like earthquakes and tsunami result in sudden change in gravity potential.

- Hence, seismic signals from events like earthquakes and tsunamis can be studied by computing temporal variation in geopotential.

Results

Achieved results including used data sets are included in the following illustrations:

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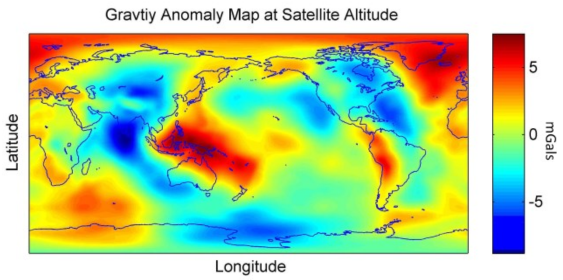

Fig. 1 Grace satellite regional gravity pertaining to study region

Sumatra Earthquake

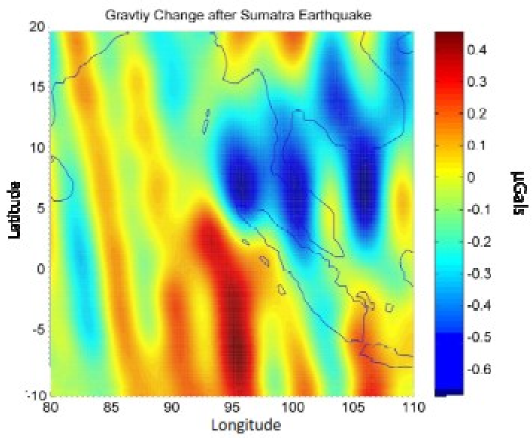

Fig. 2 Inferred gravity change after Sumatra Earthquake

Filtering details included below:

Filtering

- Higher order spherical harmonic coefficients are sensitive to instrument error.
- Lower order spherical harmonics coefficients represent seasonal phenomenon over larger landmasses.
- The extent of the rupture determines the order of the spherical harmonics which consist the seismic signals.

Spherical Harmonic Coefficients order 15 to 25

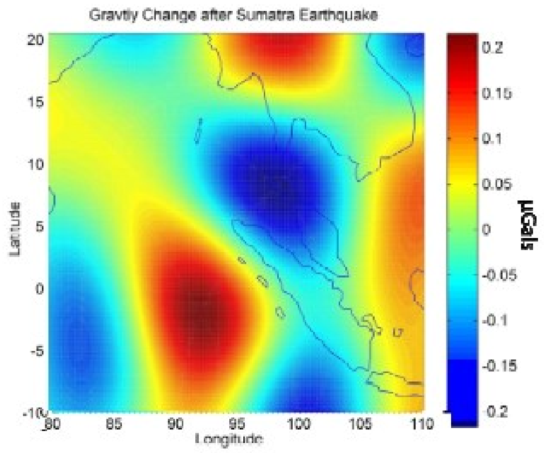

Fig. 3 Isolated gravity signature for Sumatra Earthquake

Conclusions

By considering differential satellite gravity images we were able to isolate weak gravity signals arising due to major earthquake (Sumatra Earthquake). The rupture region is clearly demarcated in the gravity picture. Both gravity and seismological modeling of the accrued results are underway.