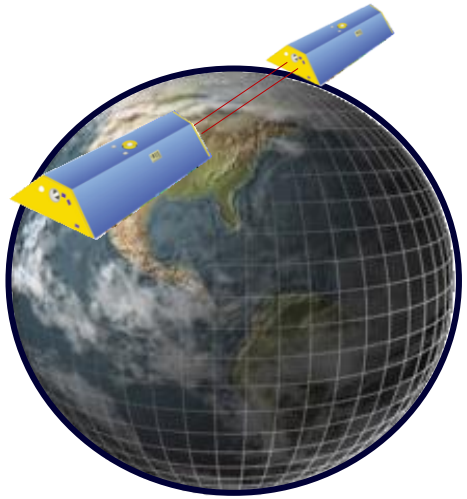
The Use of Satellite Gravimetry: Coseismic Gravity Changes in Central Chile, Sumatra-Andaman and the Earthquake in Tohoku-Oki

Presenter: Yu-Siang Lin



References

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Heki, K., & Matsuo, K. (2010). Coseismic gravity changes of the 2010 earthquake in central Chile from satellite gravimetry, Geophys. Res. Lett., 37, L24306, doi:10.1029/2010GL045335.

Matsuo, K., & Heki, K. (2011). Coseismic gravity changes of the 2011 Tohoku-Oki earthquake from satellite gravimetry, Geophys. Res. Lett., 38, L00G12, doi:10.1029/2011GL049018.

Outline

1. Introduction
2. What is GRACE?
3. GRACE data processing
4. Coseismic gravity changes of four earthquake from satellite gravimetry
5. Conclusions

Introduction

2004 Sumatra-Andaman earthquake

2010 earthquake in central Chile

2011 Of Tohoku-OKi earthquake

2004 Sumatra-Andaman Earthquake

Mainshock(Sumatra)

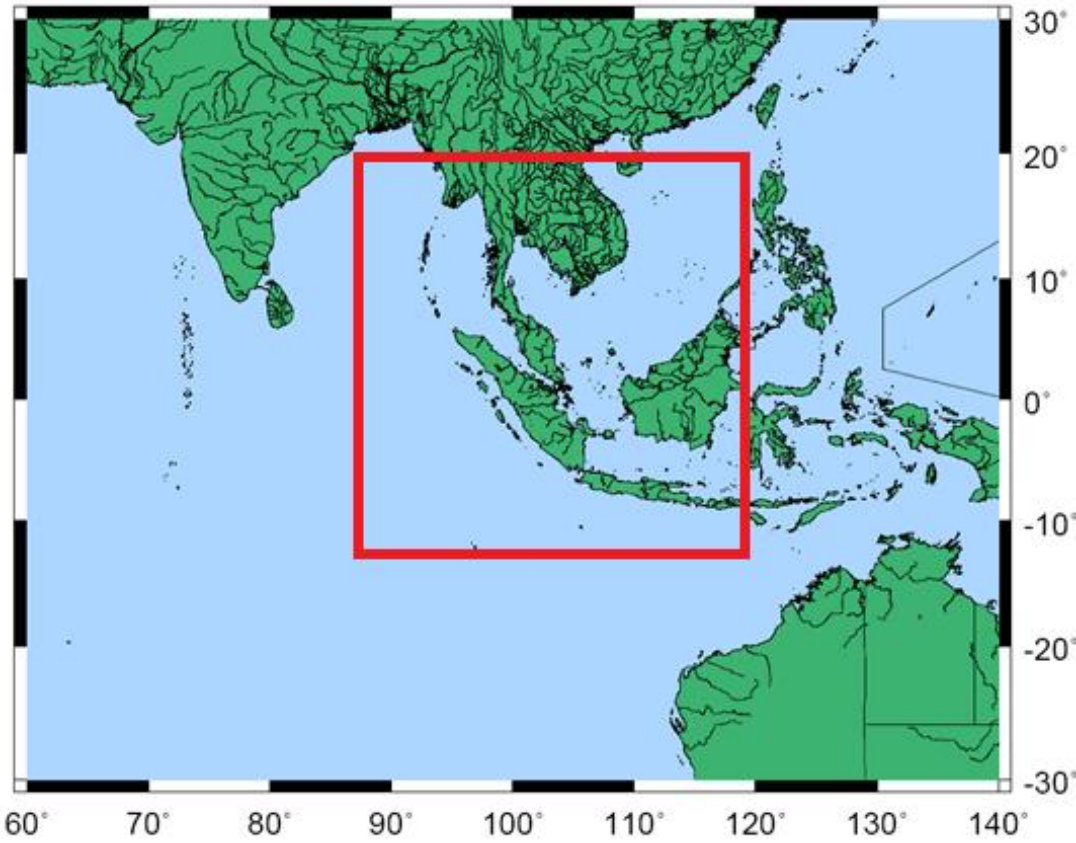
2004/12/26 00:58 Mw9.3

Depth: 30 km
Latitude : 3.19 N
Longitude : 95.52 E

Mainshock(Andaman)

2005/3/28 06:34 Mw8.7

Depth: 35 km
Latitude : 35.846 S
Longitude : 72.719 W



2010 Earthquake in Central Chile

Mainshock

2010/2/27 06:34 Mw8.8

Depth: 35 km
Latitude : 35.846 S
Longitude : 72.719 W

2011 Of Tohoku-OKi Earthquake

Mainshock

2011/3/11 14:46 JST Mw9.0

Depth: 23.7 km
Dip : 15 degree
Strike : 202 degree
Latitude : 38.10 N
Longitude : 142.86 E

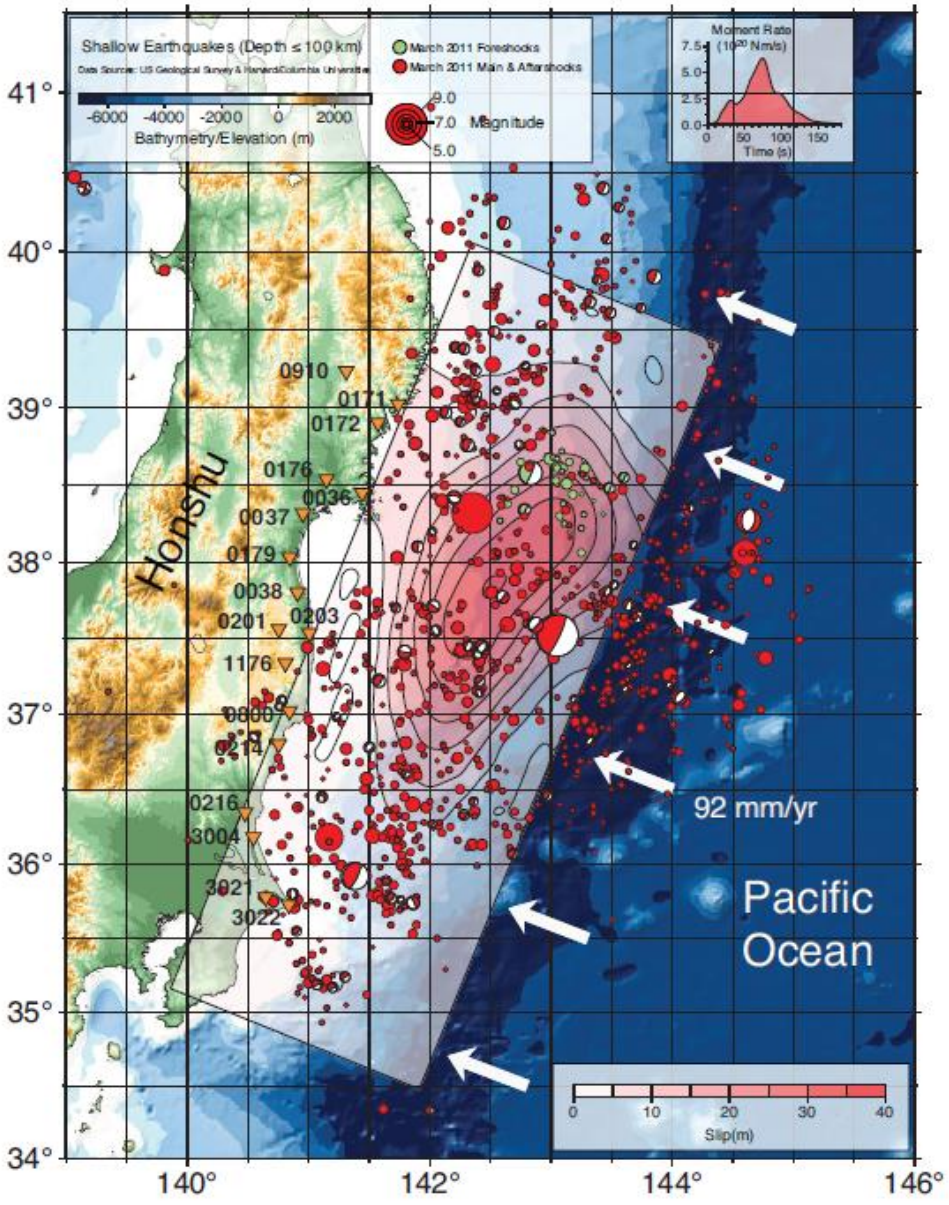
Aftershock

2011/3/11 15:08 JST Mw7.4

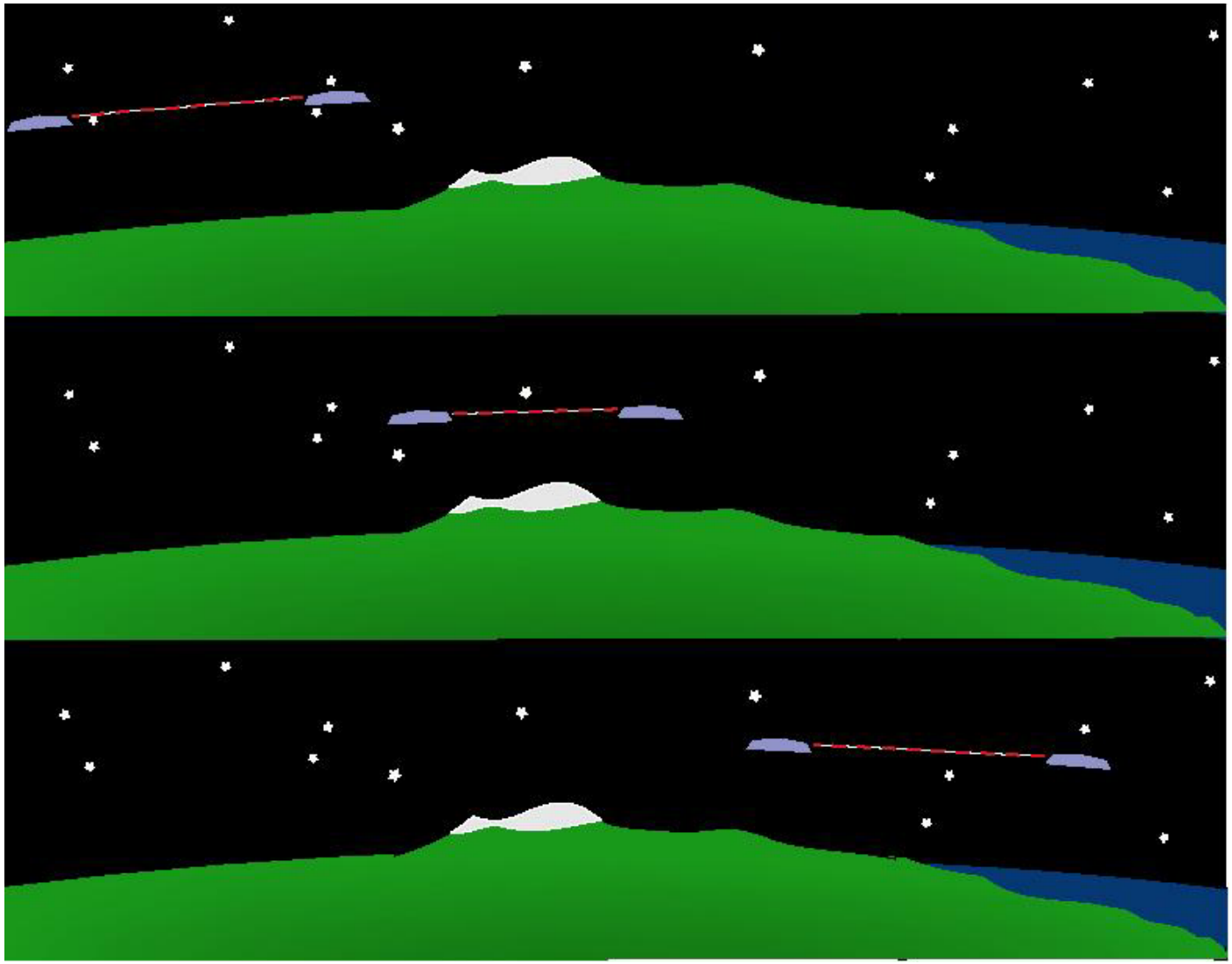
2011/3/11 15:17 JST Mw7.7

⋮

6 aftershocks of Mw > 7.0



What is GRACE?



Gravity -- What is it?

You can't see it.

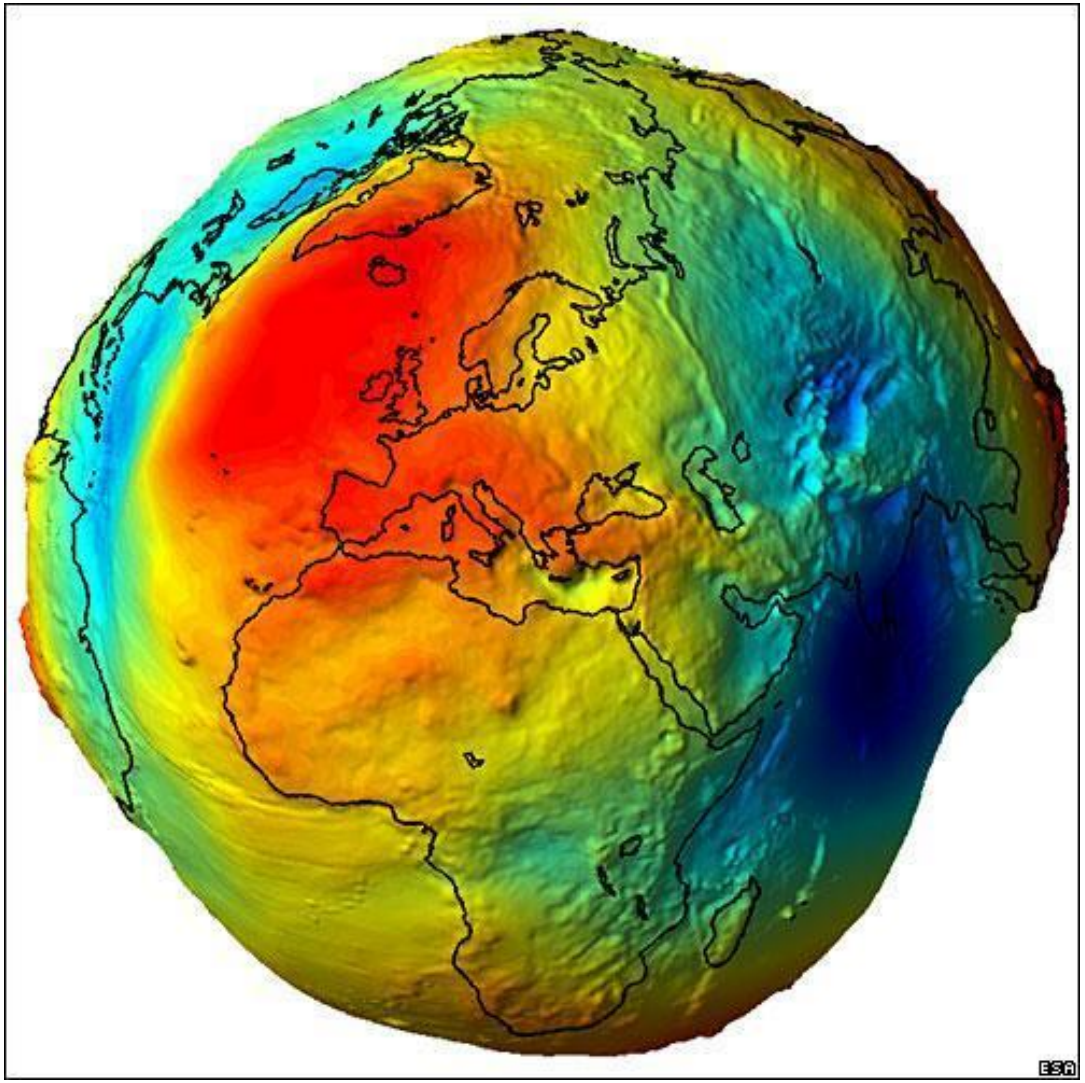
You can't smell it.

You can't touch it.

But, it's there.

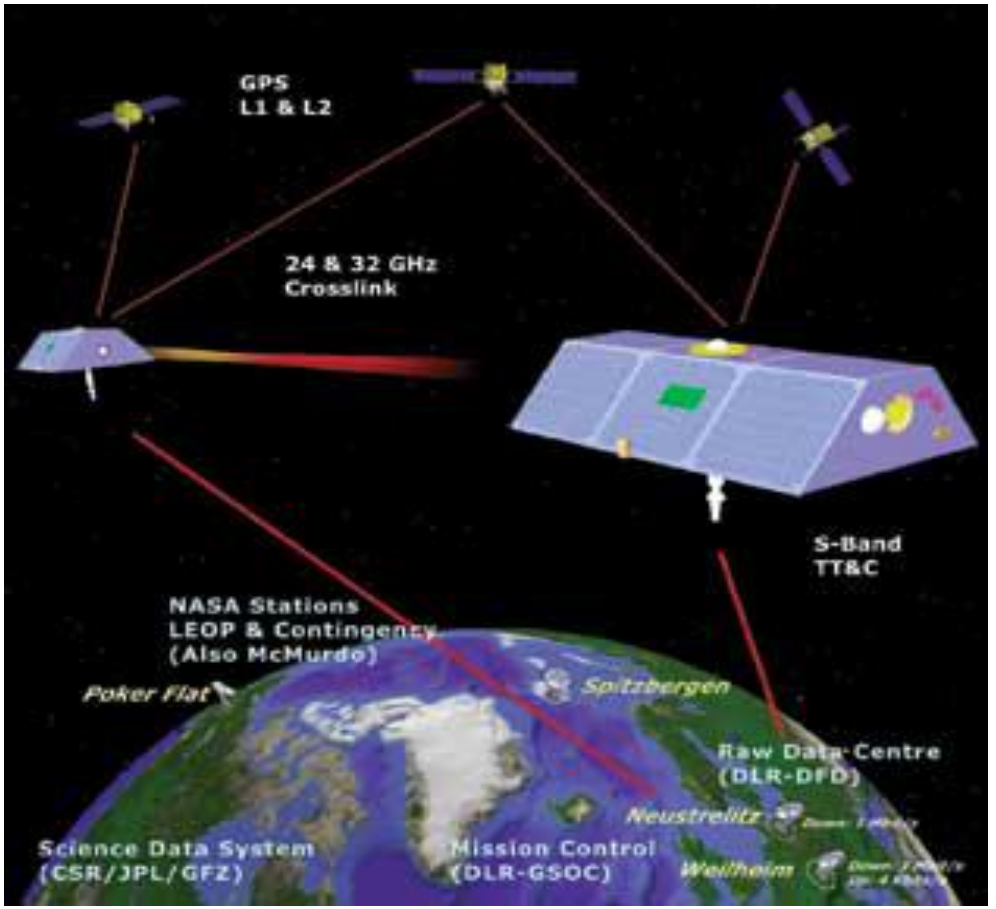
In fact, it's everywhere.

We are familiar with gravity because we live with its effects every day.



GRACE

(Gravity Recovery and Climate Experiment)



Orbit

Launched: March 17. 2002

Initial Altitude: 500 km

Current Altitude: ~465 km

Inclination: 89 deg

Separation Distance: ~220 km

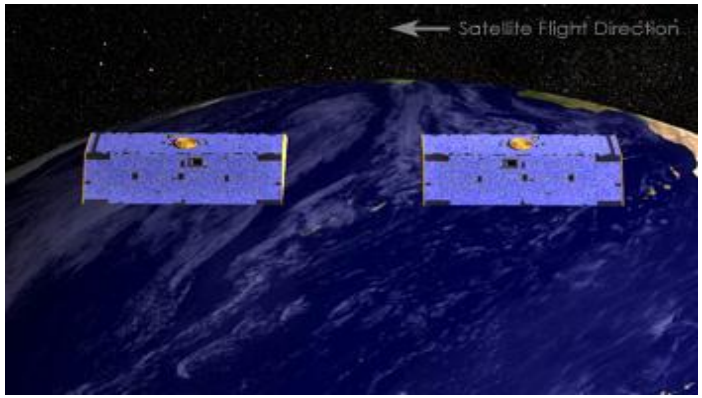
Nominal Mission : 5 years

Non-Repeat Ground Track, Earth Pointed, 3-Axis Stable

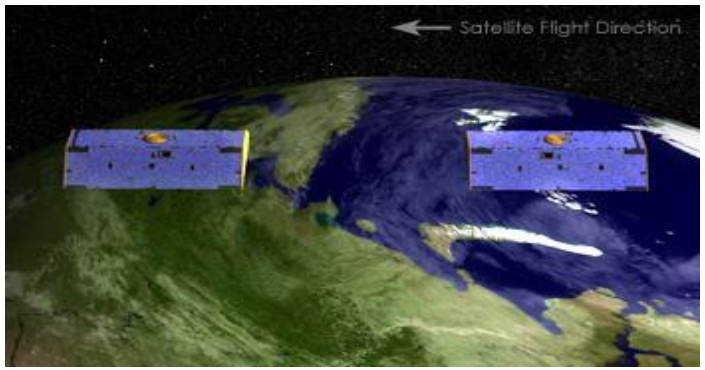
Mission Accomplishments

- **Second generation gravity models**
  - **Mean field (GGM02, Eigen-G 03)**
- **Time variable effects in gravity field are invigorating mass balance studies in Hydrology, Oceanography, Glaciology and Solid Earth Sciences**

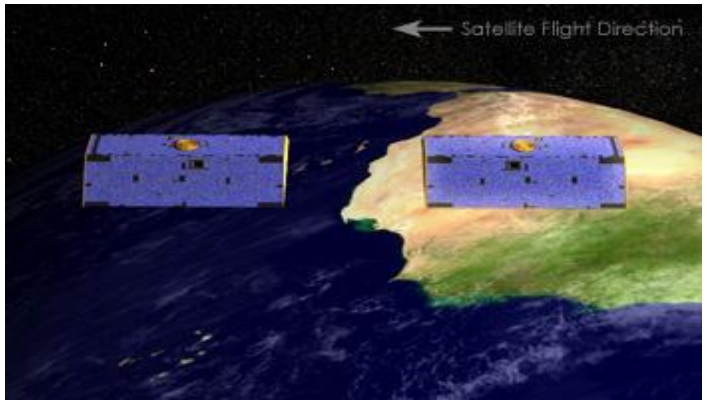
The Workings of GRACE



Distance of the two identical satellites : 220 kilometers The two identical satellites



Distance between the 2 : bigger



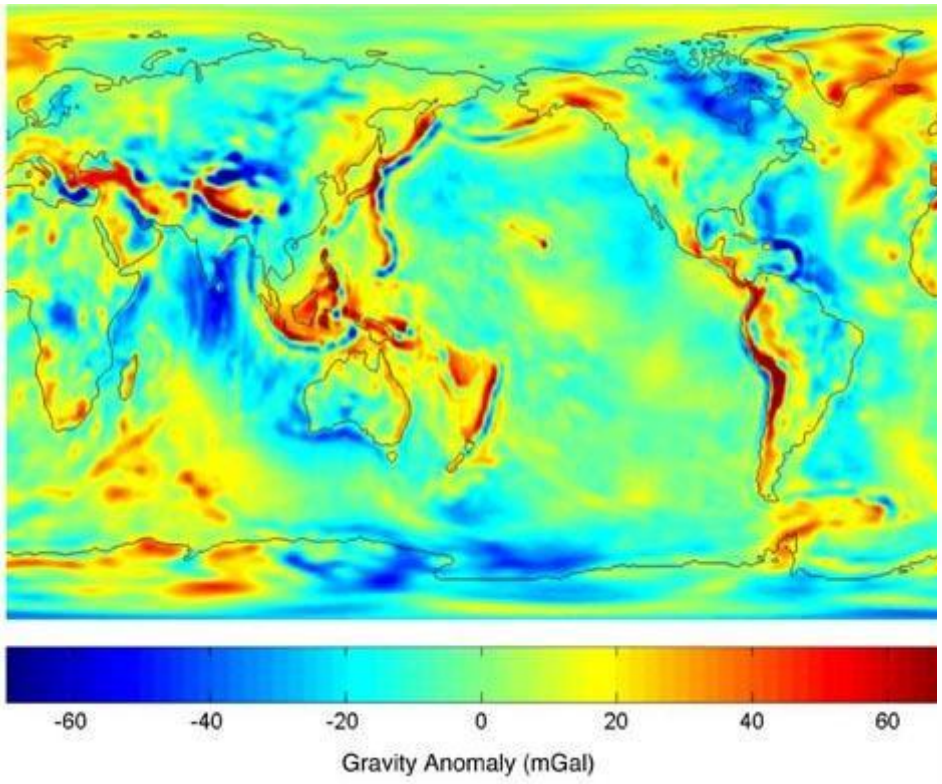
Distance between the 2: smaller

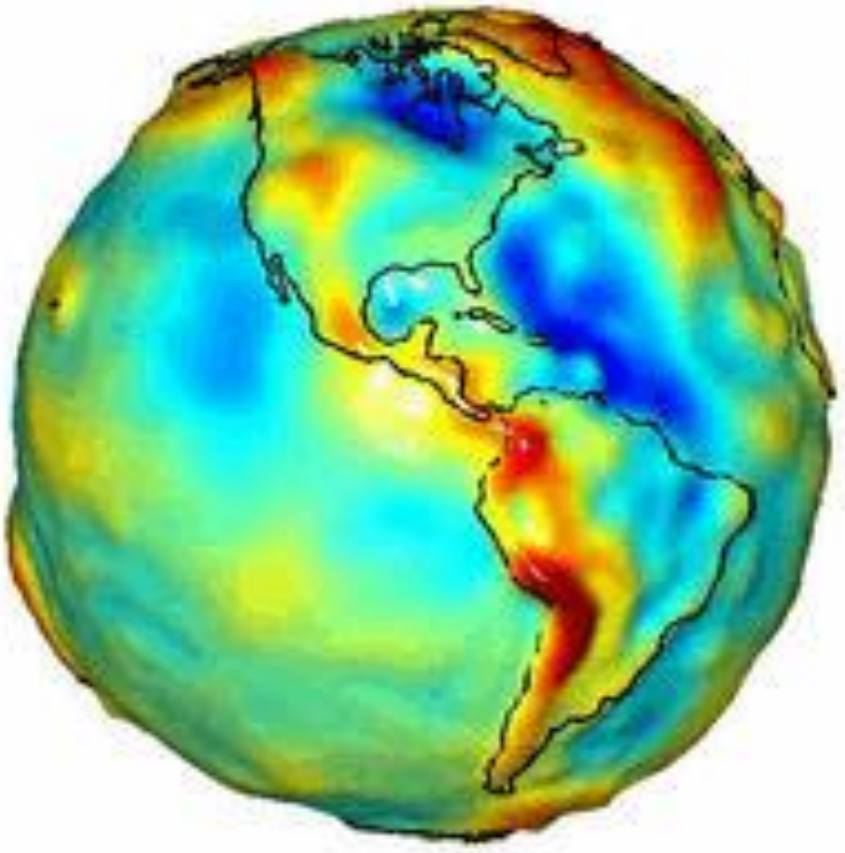
See the change with eyes (X)

precise microwave system (O)

A video about GRACE

Gravity Anomaly Maps





GRACE Data Processing

CSR Level-2 RL04 for 2002/04 – 2011/05

Max. degree 60

Stokes' coefficients

$$\text{Gravity}(\theta,\phi) = \frac{GM}{R^2}\left\{1 + \sum_{n=2}^{\infty}\sum_{m=0}^{n}(n+1)\left(C_{nm}\cos m\phi + S_{nm}\sin m\phi\right)P_{nm}(\sin\theta)\right\}$$

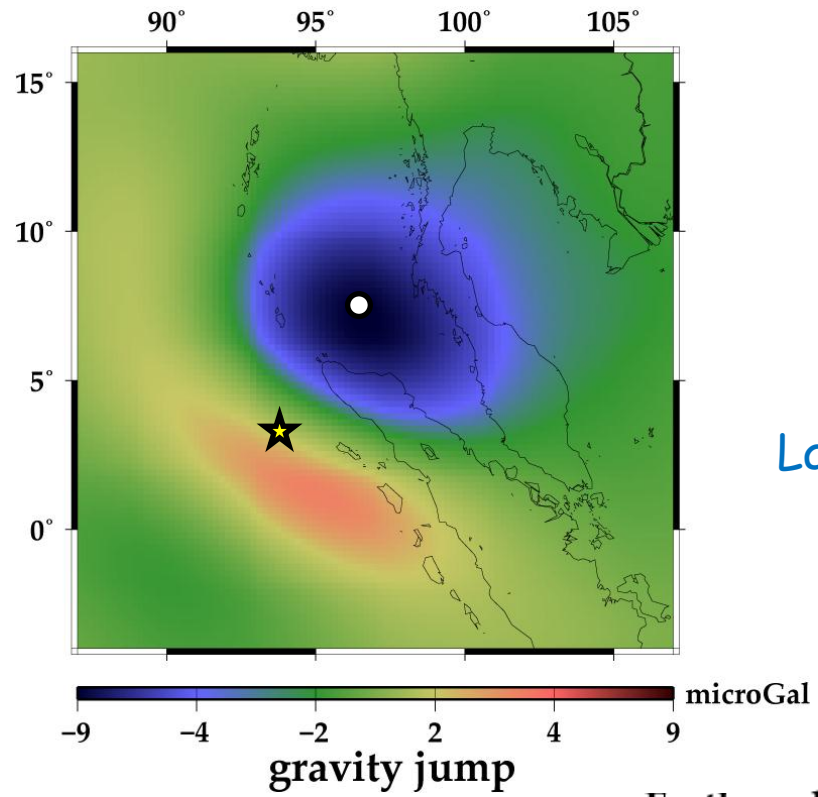
Replace C_{20} with C_{20} of SLR (Cheng and Ries, 2007)

300km Gaussian filter for spatial averaging (Zhang et al., 2009)

De-striping filter : P3M15 (Swenson and Wahr, 2006)

- where n is degree and m is order
- where (θ,ϕ) *are the spherical coordinates geocentric colatitude and* longitude
- R *is the* average radius *of the Earth*
- C_{nm} , S_{nm} *are* geopotential coefficients
- $P_{nm}(\sin\theta)$ is the n'th degree and m'th order fully-normalized Legendre function

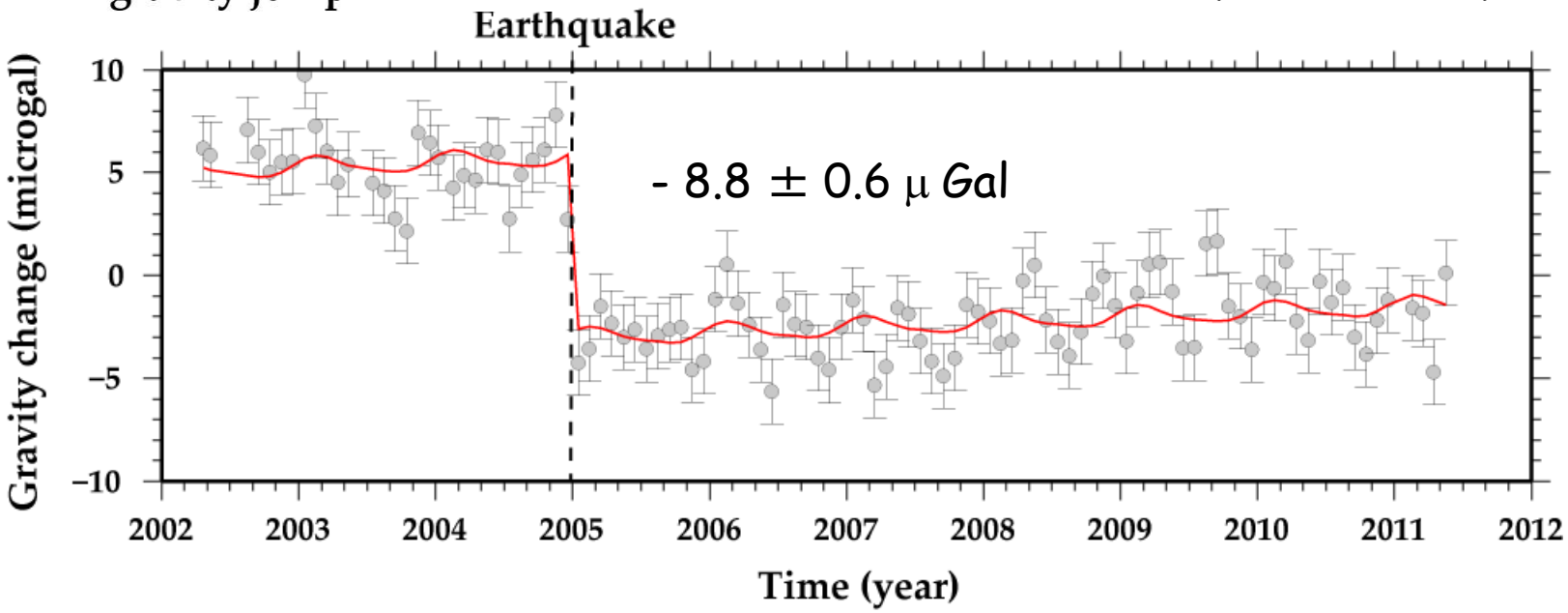
Coseismic gravity changes of four earthquake from satellite gravimetry

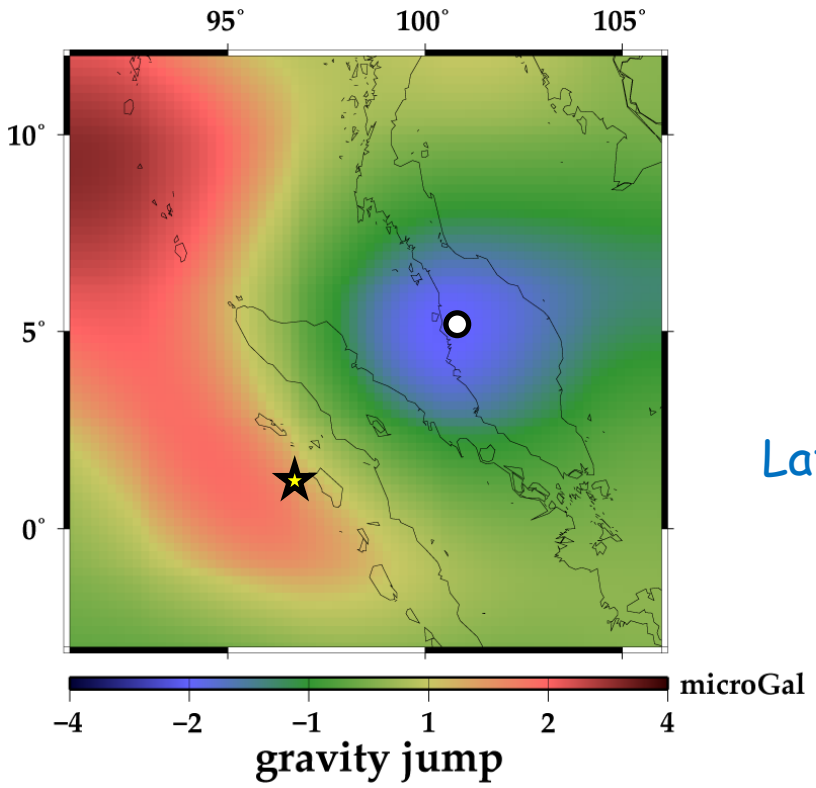


The 2004 Sumatra-Andaman Eq. Mw=9.0-9.3 (reverse)

Lat.=3.09N Lon.=94.26E Depth=28.6 km Dip=8 °

(97.0E, 7.0N)

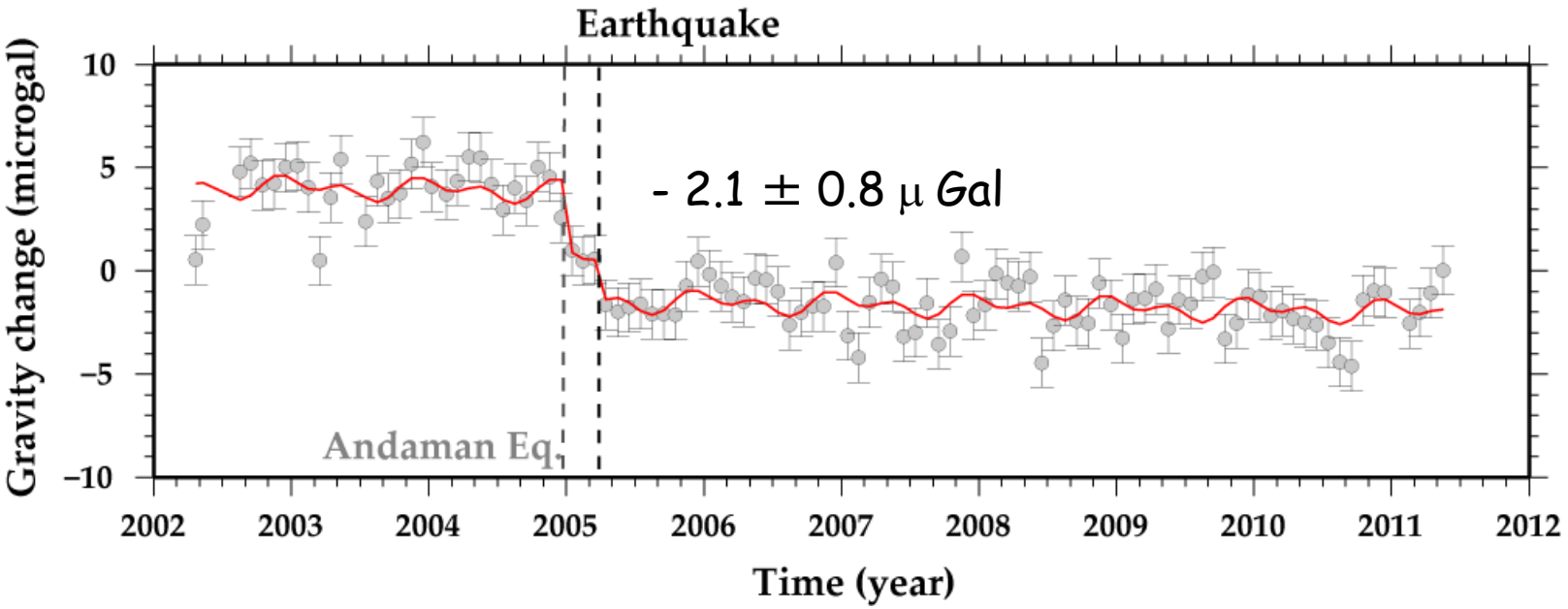


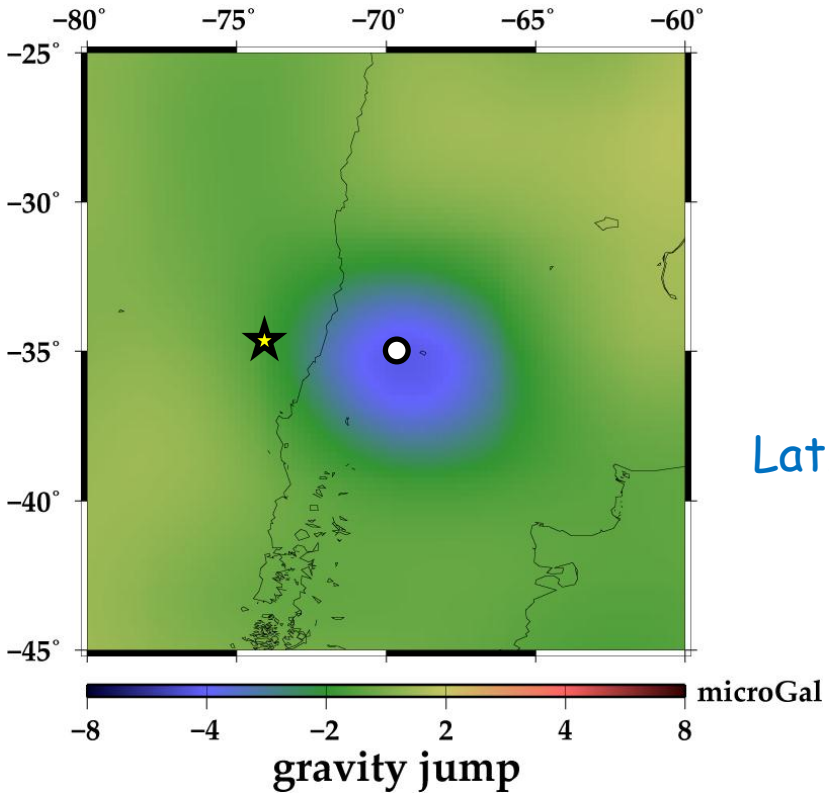


The 2005 Sumatra-Nias Eq. Mw=8.7 (reverse)

Lat.=1.67N Lon.=97.07E Depth=25.8 km Dip=8 °

(100.0E, 6.0N)

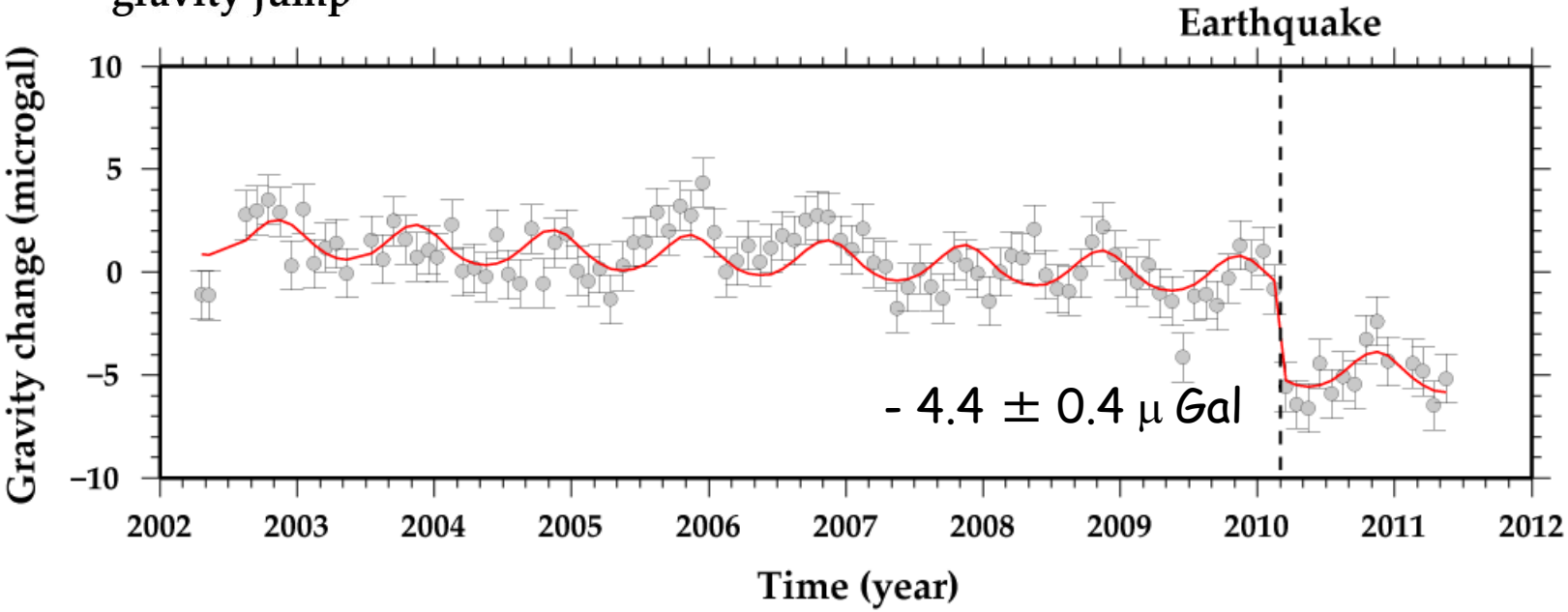




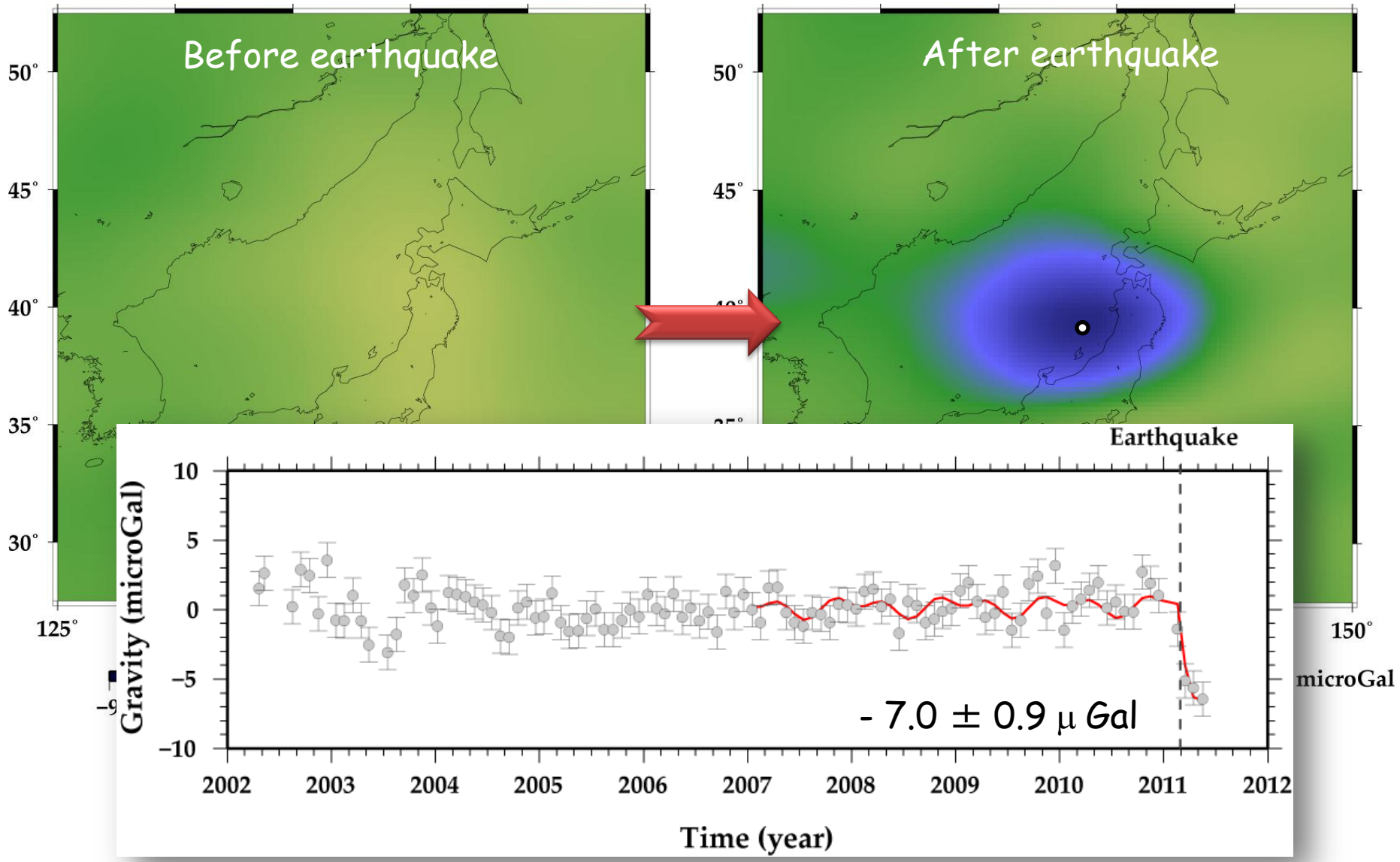
The 2010 Central Chile Eq. Mw=8.8 (reverse)

Lat.=35.98S Lon.=73.15W Depth=23.2 km Dip=18 °

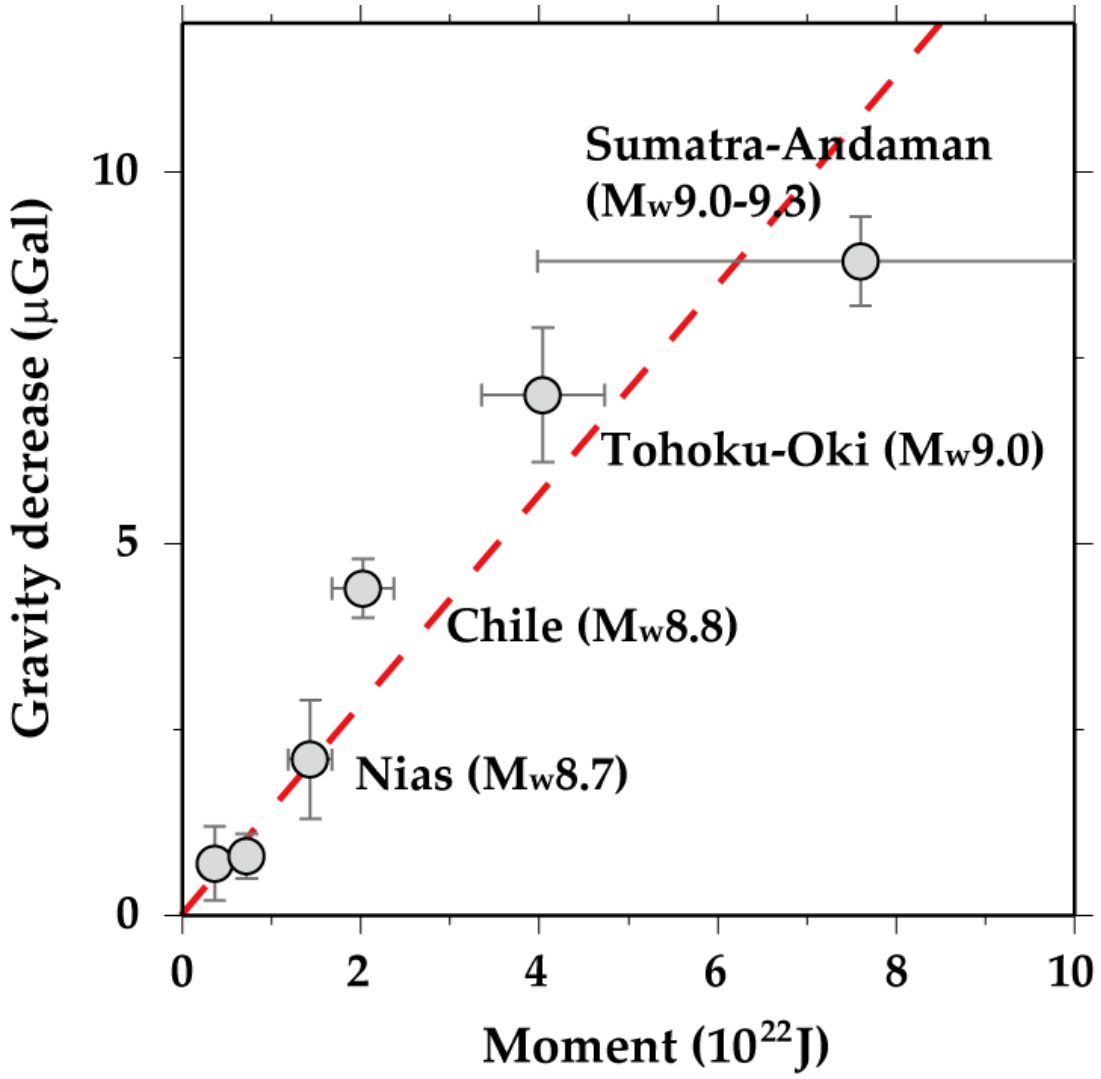
(290.0E, 36.0S)



The observed gravity changes before and after earthquake



Seismic moment versus gravity change



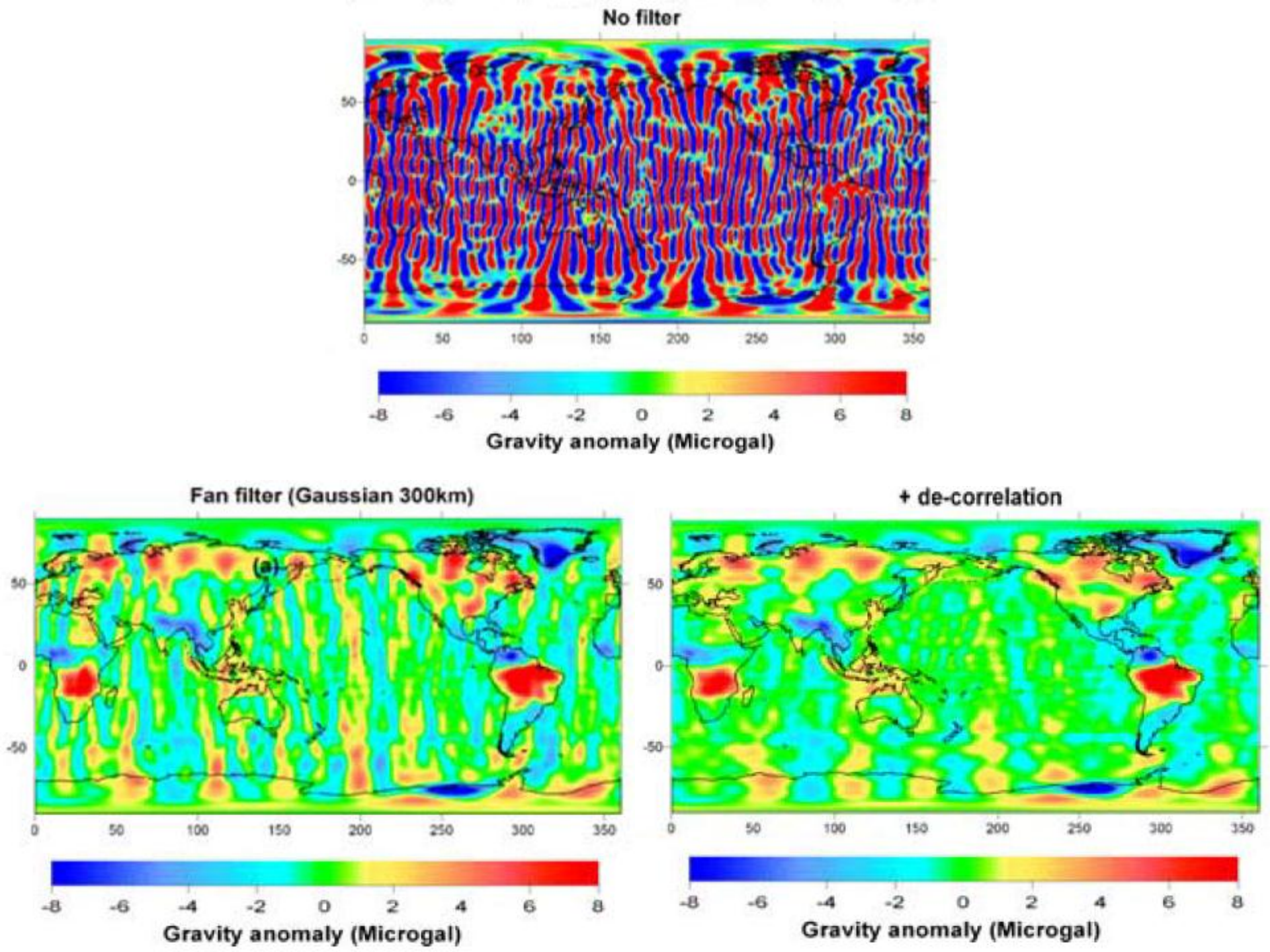
Larger earthquakes bring larger gravity changes !

Conclusions

- We compared seismic moments and maximum gravity decreases observed by GRACE. And we found linear relationship between gravity decreases and seismic moments. Larger earthquakes bring larger gravity changes.

- It appears that the gravity change roughly scales with the moment, and the threshold of their detection with GRACE seems to lie in Mw8,6-8.7.

Thank you for your attention.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Gravity anomaly (Microgal)