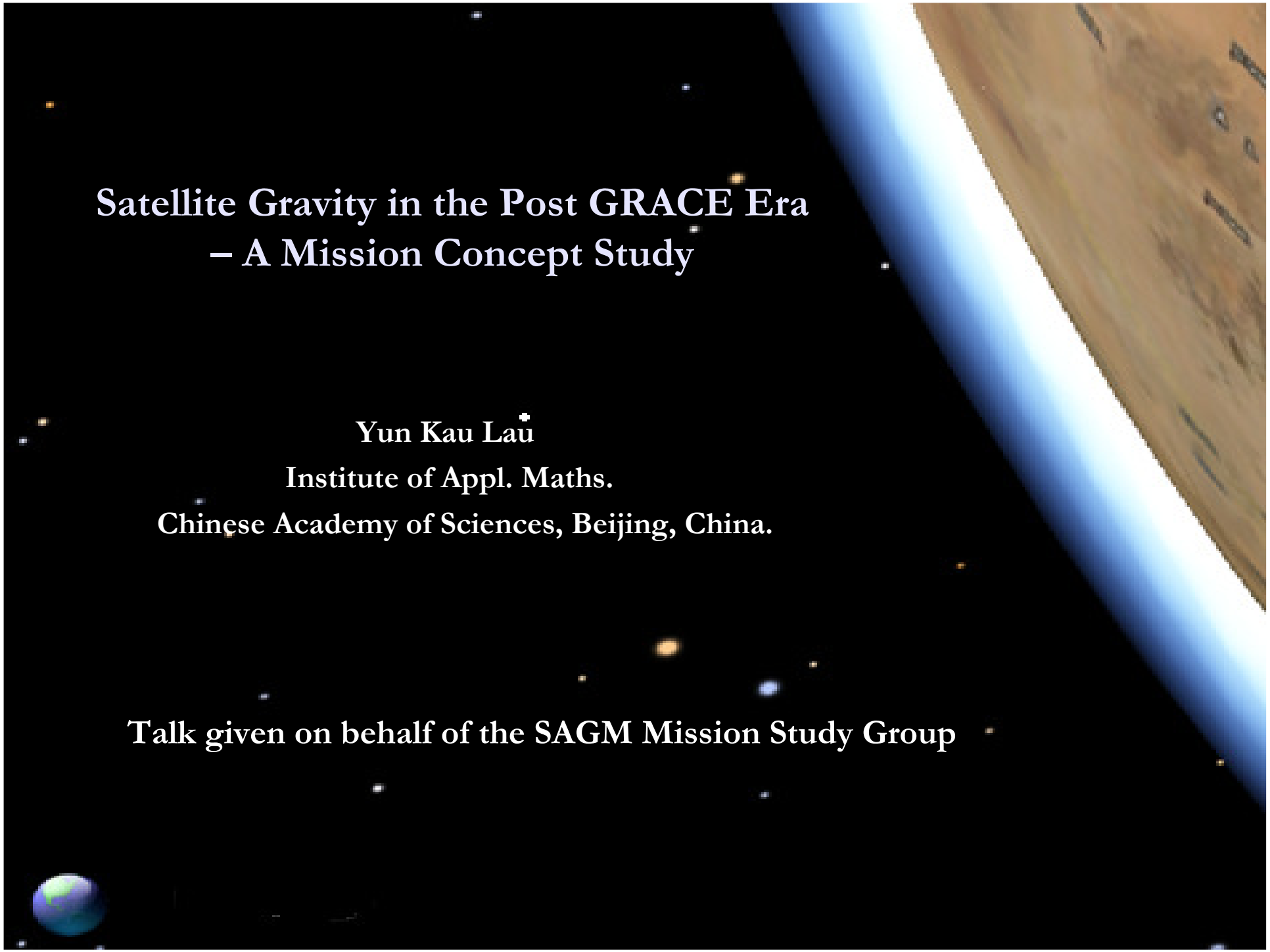


Satellite Gravity in the Post GRACE Era – A Mission Concept Study

Yun Kau Lau
Institute of Appl. Maths.
Chinese Academy of Sciences, Beijing, China.

Talk given on behalf of the SAGM Mission Study Group

Space Advanced Gravity Measurements (SAGM) Working Group

Coordinator:

National Microgravity Laboratory, Institute of Mechanics, Chinese Academy of Sciences (CAS)

Member Institutes Participating in the Study:

- Academy of Mathematics and System Sciences, CAS.
- Nanocenter, CAS,
- Dong Fang Hong Satellite Company, China,
- Huazhong University of Science and Technology,
- Institute of Atmospheric Physics, CAS,
- Institute of Mechanics, CAS,
- Institute of Physics, CAS,
- Shanghai Engineering Center for MicroSatellites, CAS,
- Wuhan Institute of Geodesy and Geophysics, CAS,
- Wuhan Institute of Physics and Mathematics, CAS.

Objectives of the working group

- Preliminary mission concept study of a post GRACE mission.
  (Two co-orbiting drag-free satellites with laser ranging)
- Understand the potential of scientific discoveries.
- Anatomy of the key technologies of the prospective mission.
  (Laser interferometry, GRS, drag-free spacecraft design)

Guiding Principles for the study:

1. A launching date sometime after 2020.
2. Technologically viable for China.
3. China makes significant contributions to sciences using satellite gravity mission.
4. Primary scientific objectives: climate and environmental change, earthquake studies, hydrology and water resources, especially within China.

Mission Design

Expected range of key parameters for instruments design

Distance between two S/Cs: 50–200 km
Optimal choice of distance?
Altitude of orbit in relation to measurement sensitivity: 350–450km
Drag free performance – residual acceleration

10^{-10} to 10^{-12} m/(s^2 √Hz) (0.1 Hz)

Precision of laser metrology: μm to nm/ √Hz (0.1 Hz)

Key Technology Development

- Laser metrology, laser frequency stability

  (Institute of Mechanics, Huazhong, Wuhan Institute of Physics and Mathematics)

- Gravitational Reference Sensor

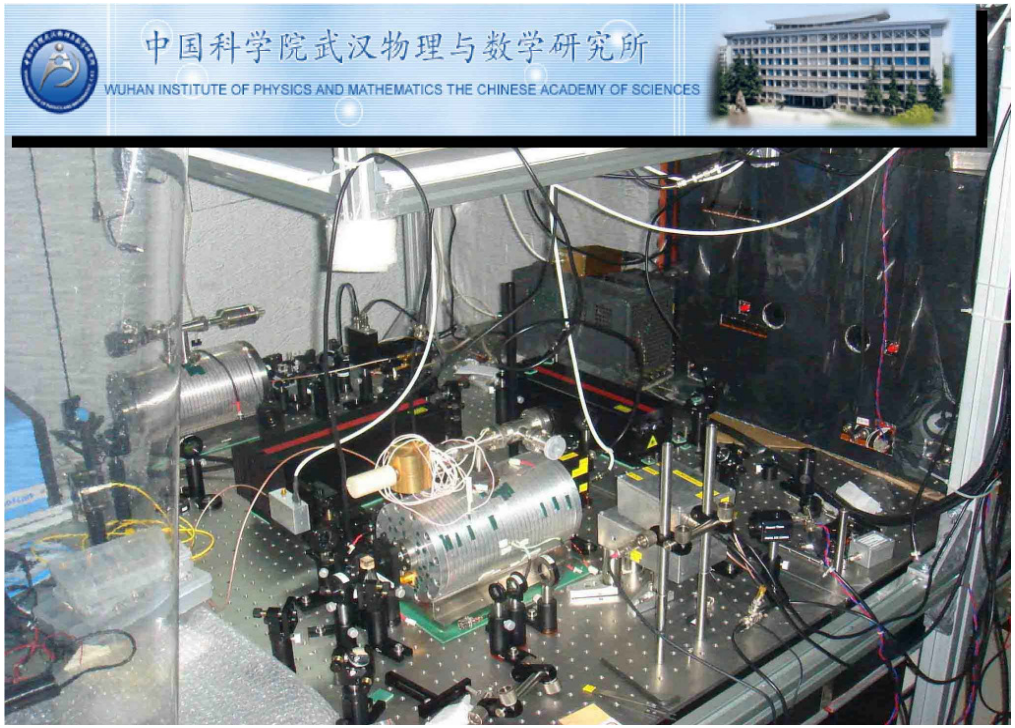
  Capacitance sensing -- Huazhong

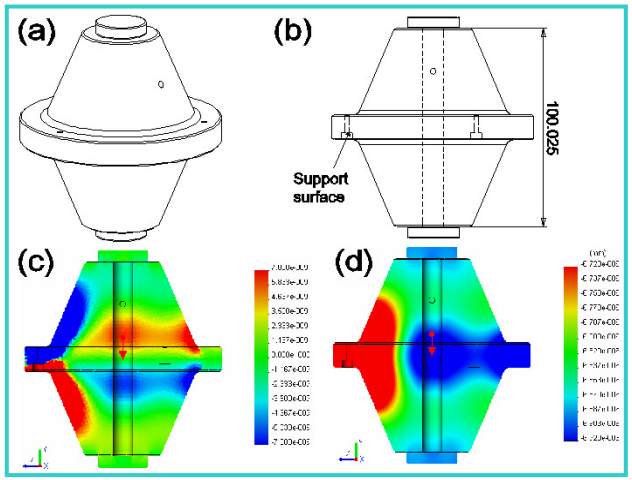
  FEEP thruster and DFC – Institute of Mechanics, DFH Company

- Drag-free Satellite Platform

  (DFH Company, Shanghai Microsatellites)

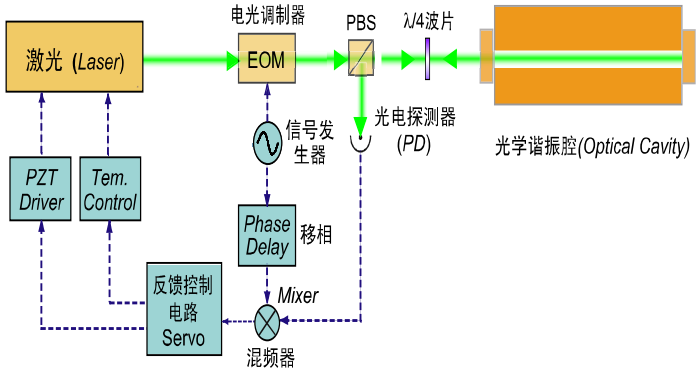
Experiments on frequency locking of Nd:YAG lasers





Ongoing experiments in the Wuhan Institute of Physics and Maths, CAS

Frequency locking of Nd:YAG lasers

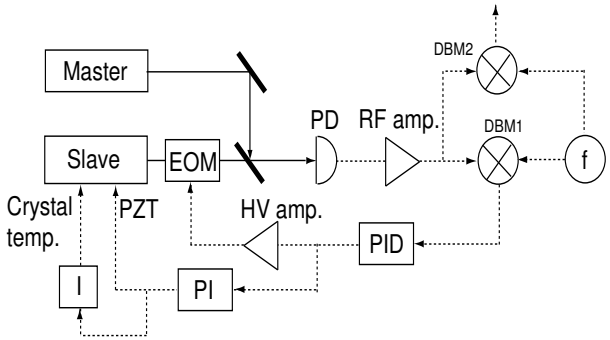


■Projected system performance:

■Frequency noise: 30 Hz/√Hz (10mHz-100mHz),

■Frequency drift: <10 kHz/hour

Phase lock of two Nd:YAG lasers



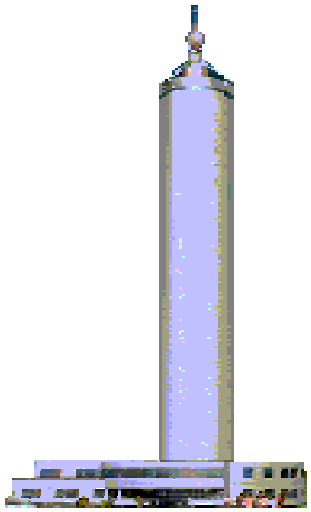
- Analog PLL(Phase Lock Loop) experiments

  Projected phase noise：$1x10^{-4}$ rad/√Hz (10 - 100 mHz)
- Digital PLL – design and experiments

  a.digital phase detector

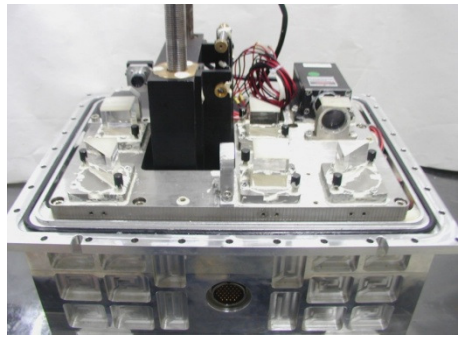
  b.analysis of phase noise
- Our goal: Increase the gain at low frequencies (1 mHz-1 Hz) while extend the unit-gain frequency up to several MHz.

Laser metrology
(host institute: Institute of Mechanics)
+ more institutes in future



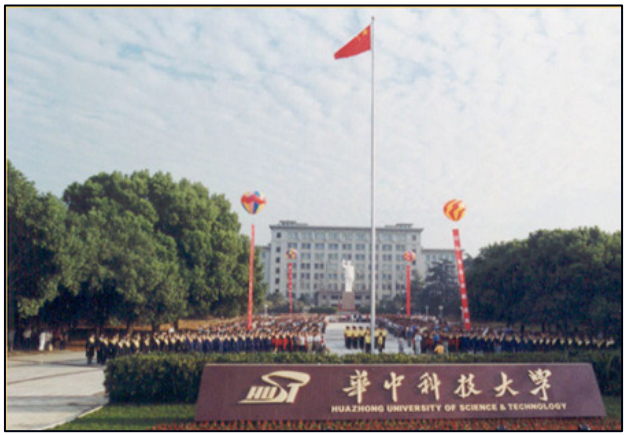
Technical Elements of Laser Metrology for Space Science Missions

- **Optical bench**
  - **heterodyne interferometry**
  - **collimation**
  - **weak-light phase locking**
- **Phasemeter**
  - **phase measurement**
  - **ultra-stable oscillator (USO)**
- **Environment**
  - **thermal shielding and control**
- **Accessory**
  - **electrical/optical cables**
  - **Connecters**
- **Telescope**

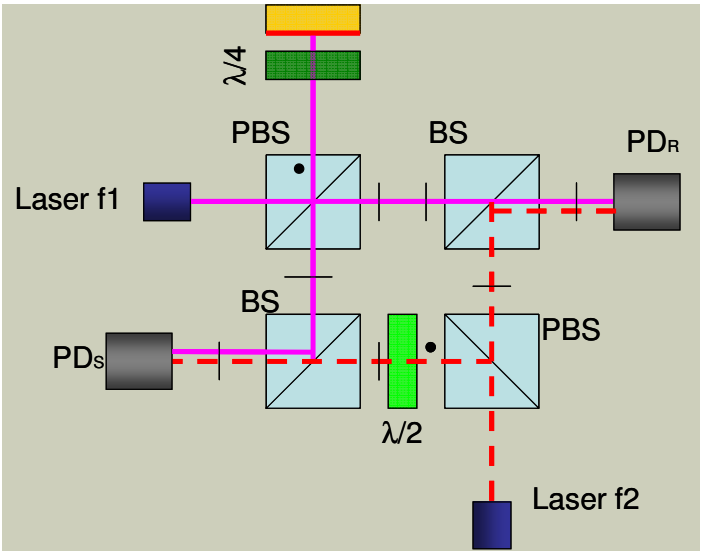


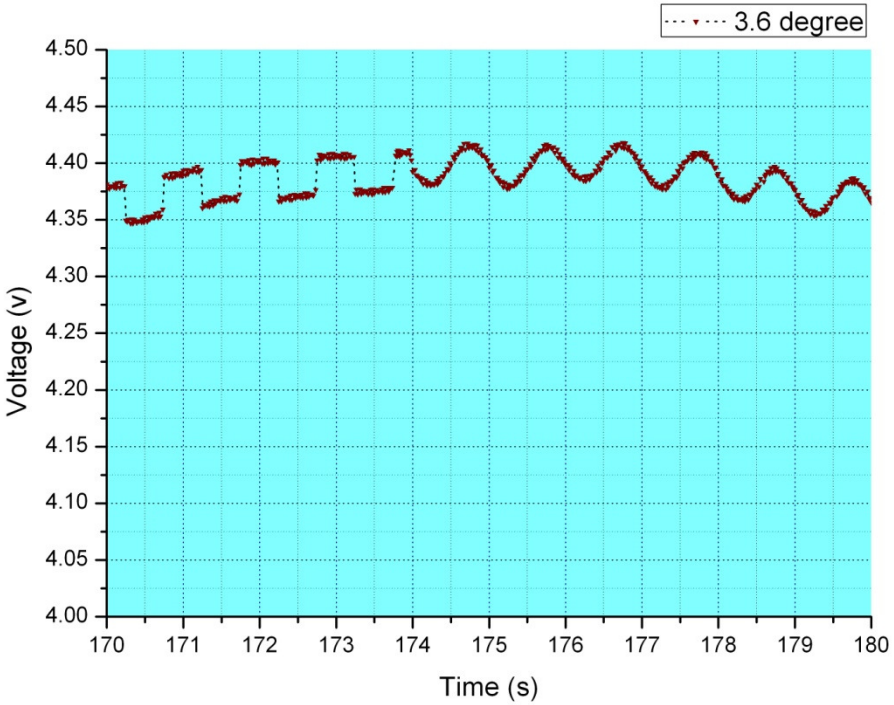
Research Roadmap of Space-Based Interferometry in Huazhong University of Science and Technology, Wuhan.

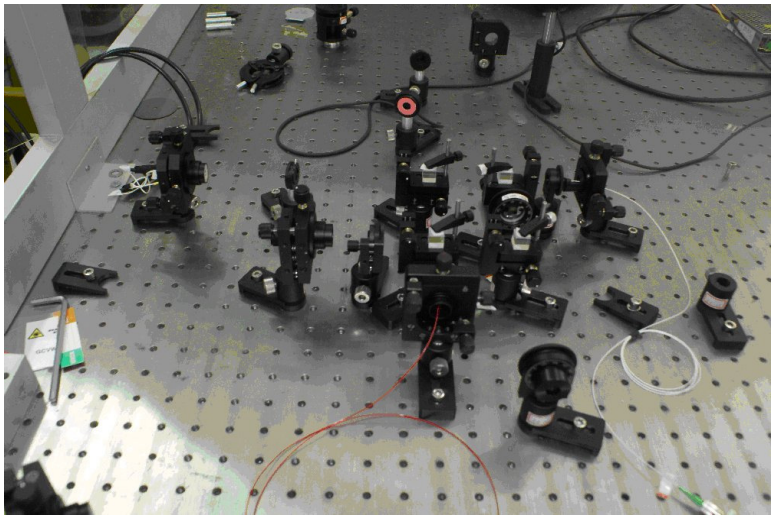
- Breadboard interferometer with nanometer resolution (2008)
- 10-m prototype of heterodyne interferometry (2009)
- Prototype of nanometer interferometry for Chinese GRACE (201?)
- Chinese GRACE
- Prototype of picometer interferometry for Chinese LISA (202?)
- Chinese LISA



Preliminary Results for Phase Meter in HUST

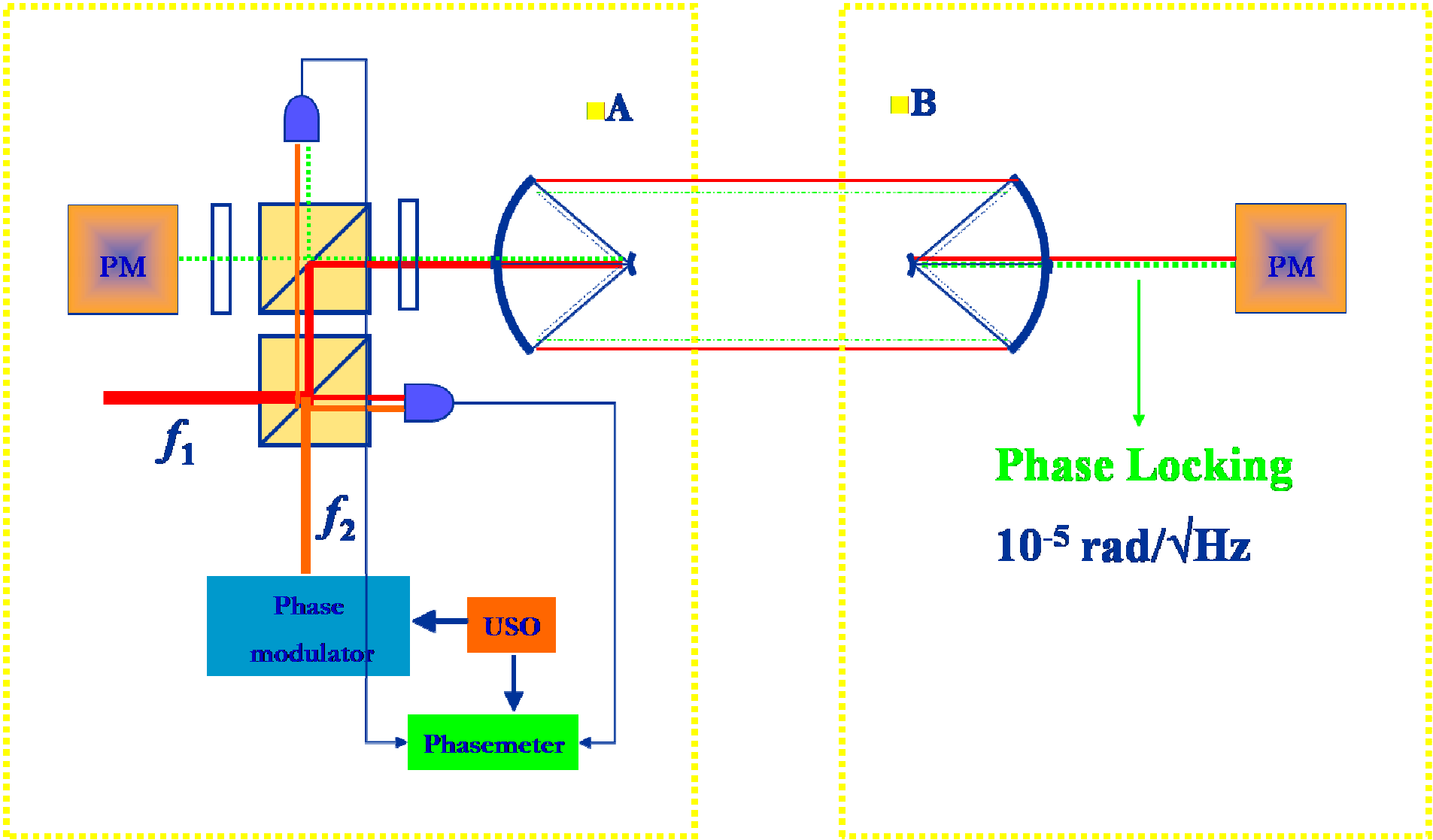






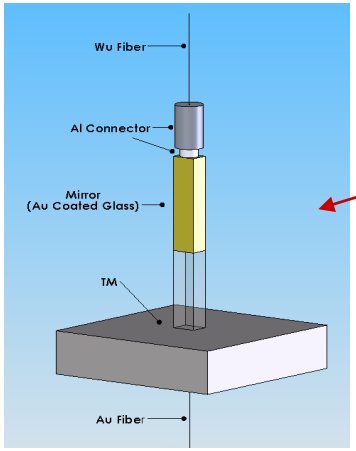
- 3.6°-phase modulation
- measured by phasemeter

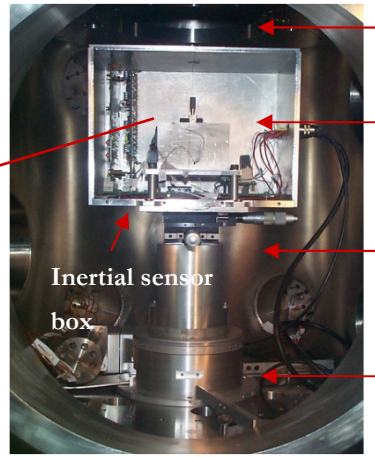
Heterodyne Interferometer with A Long Baseline



Inertial Sensor Development in HUST

Torsion Pendulum
Sensitive to torque





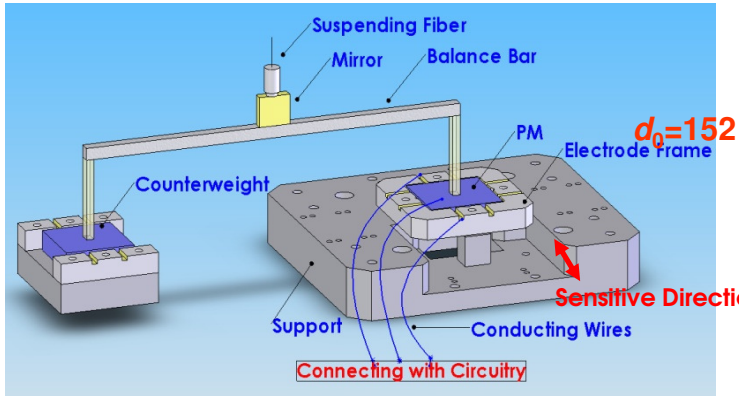
fiber

frame & TM

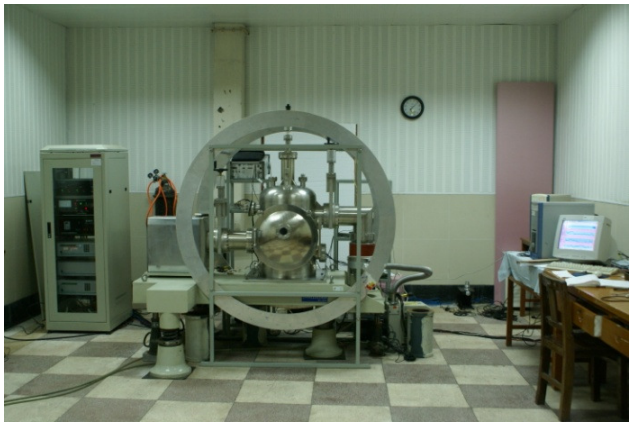
micro-operation platform

turntable

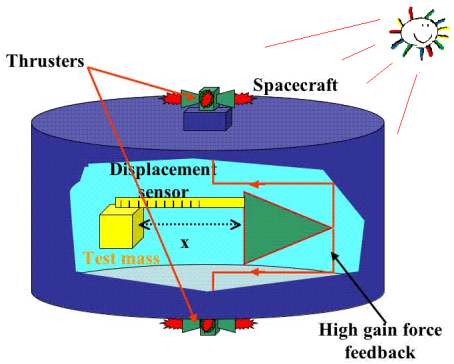
Torsion Balance
Sensitive to direct force



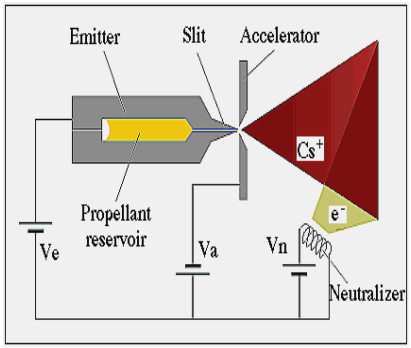
d_0=152 um

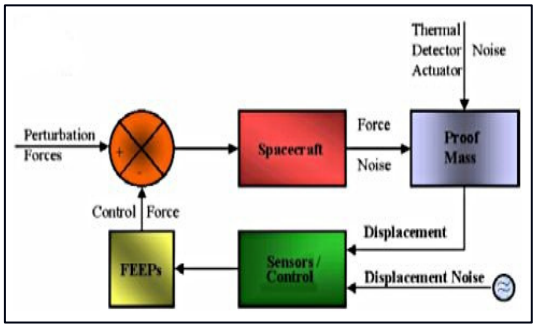


Require studying more DoFs simultaneously such as coupling.



Dragfree Control and Satellite Platform





Ion truster and control loop --

Dong Fang Hong Small Satellite Company and Institute of Mechanics.

Dragfree Satellite Platform Construction

--- Dong Fang Hong Satellite Company and Shanghai Engineering Center for MicroSatellites, CAS.

Feasibility Study

A global and thorough understanding of the mission concept (everything from first principle!)

- Identify key problems to be tackled!
- Orbit design.
- Instrument noise modelling (laser metrology, inertial sensor, numerical simulation of S/C dynamics …..) .
- Sensitivity in gravity field recovery given the instrument and geophysical background noise.
- Preliminary study of data management before level 1B.

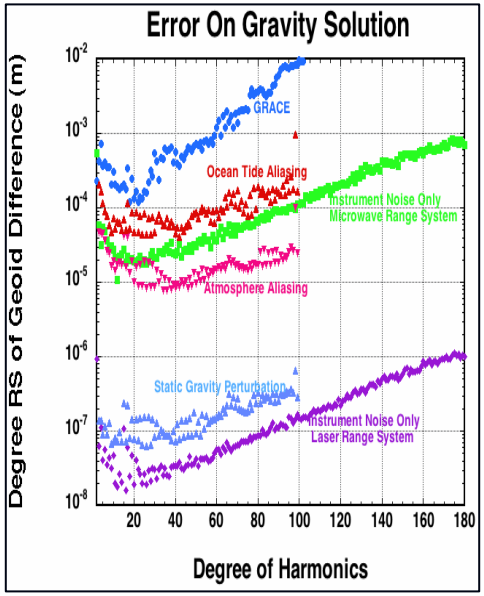
+ … more

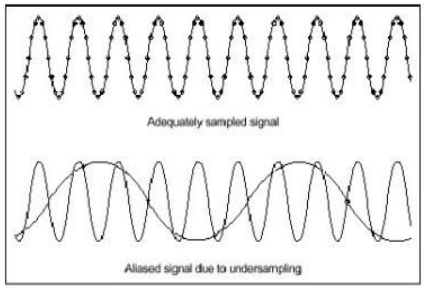
Issues under consideration

- Sensitivity curve of geoid measurement due to instrument noises and GPS errors.
- Time and spatial aliasing in relation to measurement sensitivity.

  Better modelling of geophysical background noise? Probably not.

  Flight formation? Data analysis strategy?

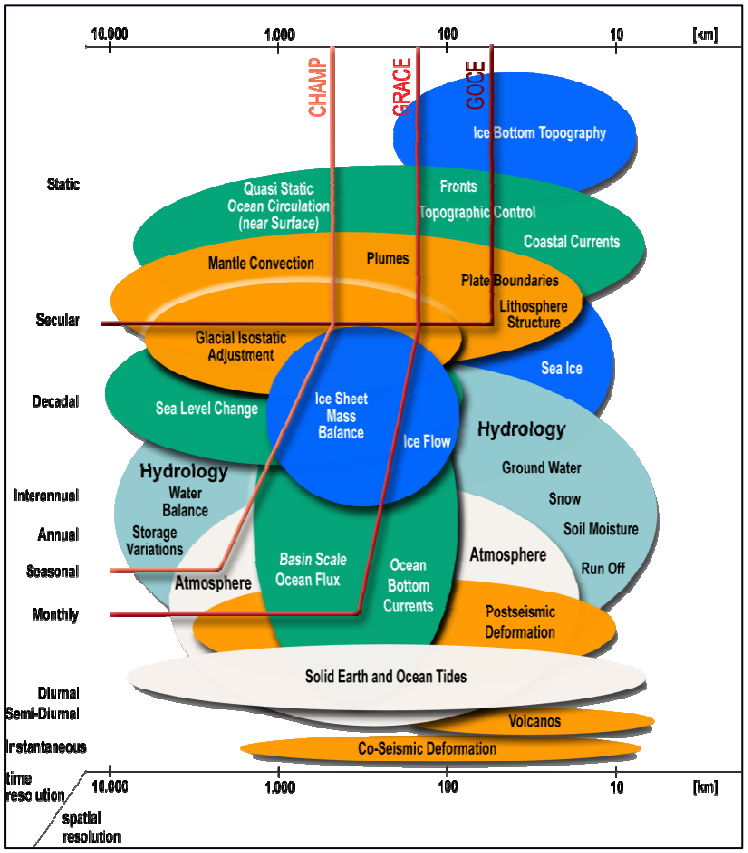




Prospective Science Drivers

- Hydrology
- Seismology
- Climate Change
- Question:

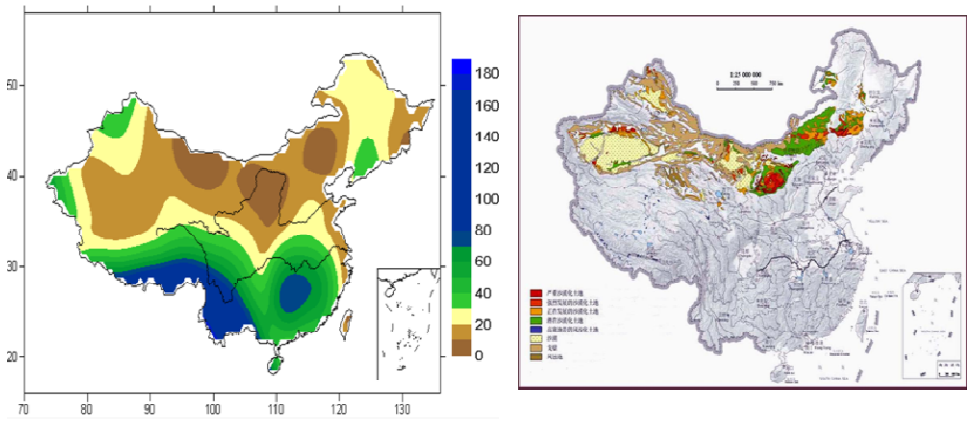
  Which contemporary scientific questions can one address given the instrument sensitivity and signal aliasing in the presence of errors in the "background" models?



Science Drivers and Gravity Field Recovery

(Institute of Geodesy and Geophysics, Wuhan, CAS + other institutes)

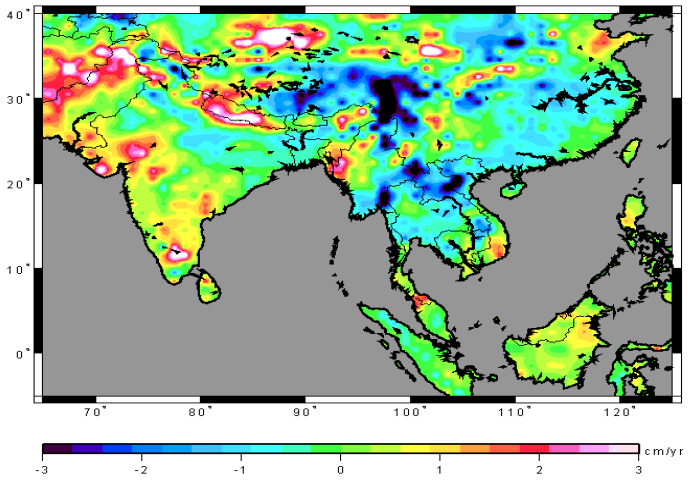
Seasonal variations of water storage over China



Using 6 years GRACE observational data, we can obtain a clear water storage variation map with small annual changes in North of China, and large annual changes in South of China. (400 km, Gaussian filter)

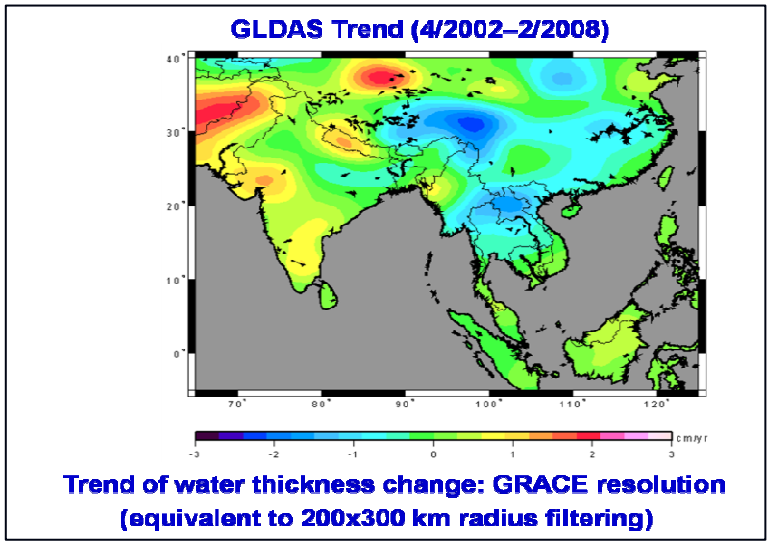
Hydrology Simulation over Asia

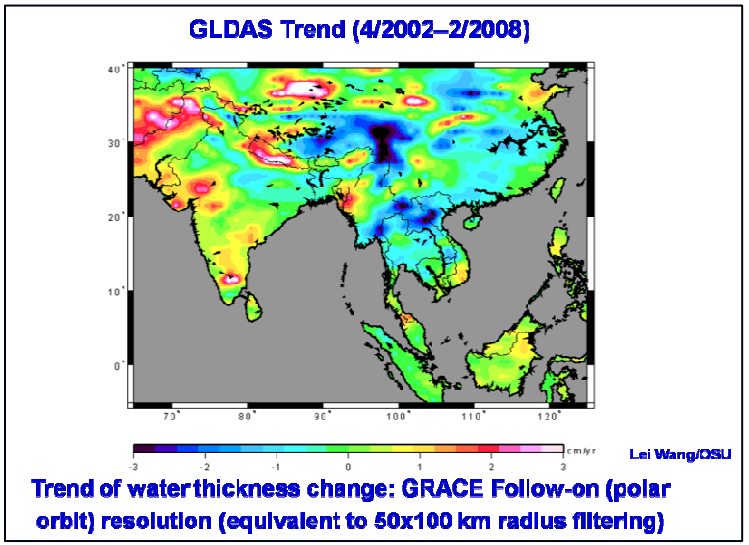
(Lei Wang, C.K.Shum)



Trend of water thickness change computed using the GLDAS Model

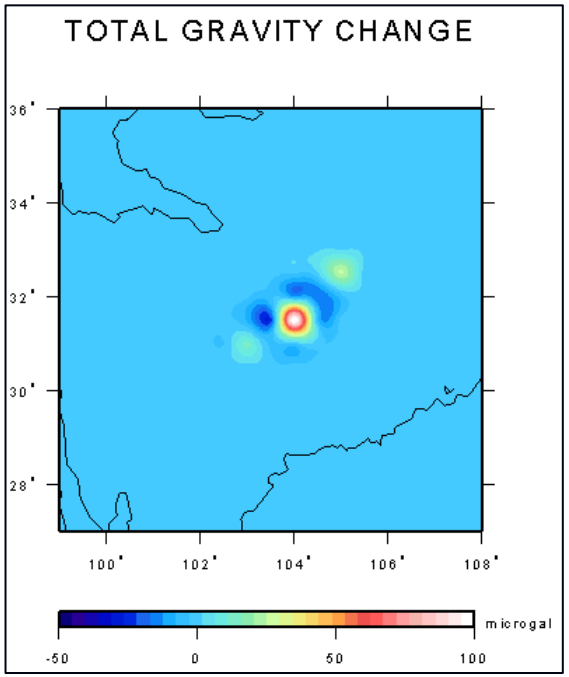
(2002.4 to 2008.2): 1 degree by 1 degree



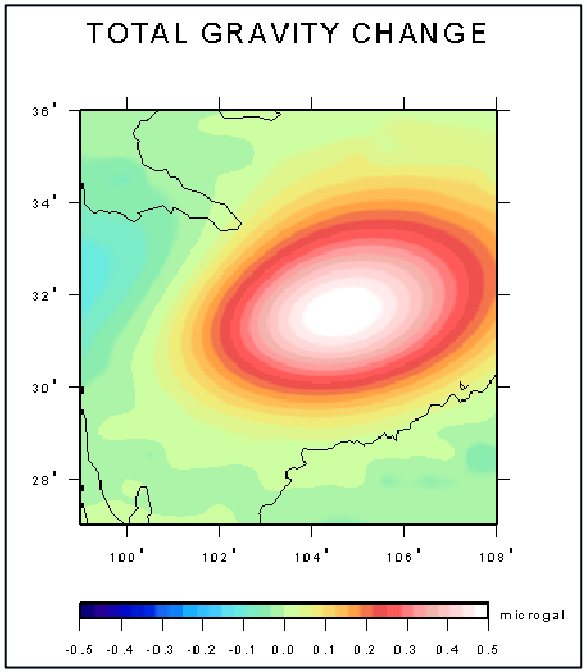


Coseismic Deformation from Wenchuan Earthquake, Mw=7.9

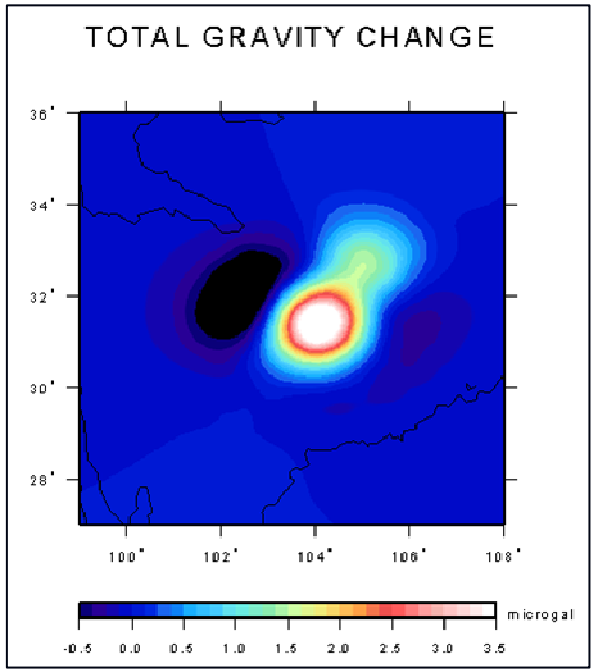
(Lei Wang, Ji Chen, C.K.Shum)



Gravity change predicted by seismic model
(50 km grid) [Chen Ji]



GRACE observed gravity change (simulated)
200x300 km radius filtering



GRACE Follow on observed gravity change
(simulated):
50x100 km radius filtering

Thank You!