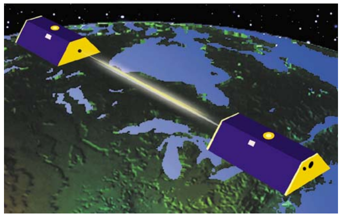
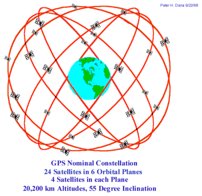
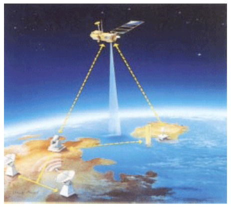







Global Inverse for Surface Mass Variations, Geocenter Motion, and Earth Rheology

Xiaoping "Frank" Wu

Objectives

- Seasonal to Interannual Mass Variation: Elastic Earth
  - Multi-satellite data combination to achieve complete global coverage **GRACE/GPS/Topex/Jason**
  - Degree-1 mass harmonic and geocenter motion
  - Accuracy improvement
- Secular Simultaneous Inversion Development: Viscoelastic Earth
  - Dynamic Approach: Secular present-day trend + GIA or PGR
  - Kinematic Approach: Present-day trend and PGR spherical harmonics
  - Secular geocenter motion and International Terrestrial Reference Frame

Publications (2006-2008) and Support

X. Collilieux, Z. Altamimi, J. Ray, T. van Dam, and **X. Wu**, Geophysical Excitation of translational and radial motions in the international laser ranging network, *JGR, to be submitted,* 2008.

Wu, X., R. G. Blom, E. R. Ivins, and M. Zhong, Inverse and probabilistic methods for Geophysical Applications of GRACE gravity data, *JGR, in review,* 2007.

Wu, X., M. B. Heflin, E. R. Ivins, and I. Fukumori, Seasonal and interannual global surface mass variations from multisatellite geodetic data, *J. Geophys. Res., 111,* B09401, doi:10.1029/2005JB004100, 2006.

Zhong, M., H. Yan, **X. Wu**, J. Duan, and Y. Zhu, Non-tidal oceanic contribution to polar wobble estimated from two oceanic assimilation data sets, *J. Geodynamics, 41,* 147-154, 2006.

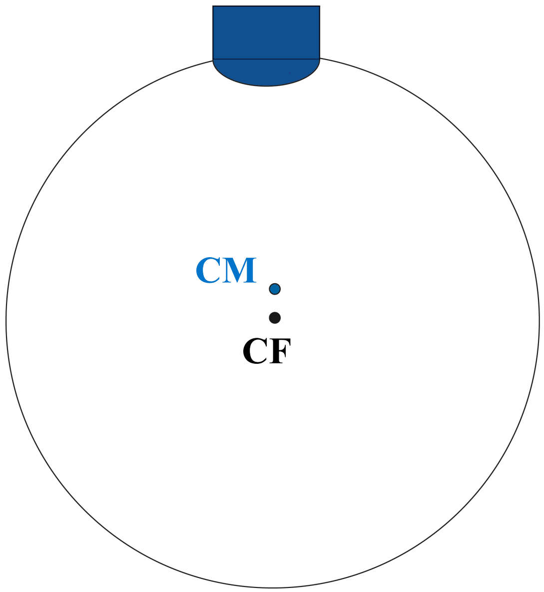
Current Support

NASA ESI GRACE Program:	FY2008 - 2010, $160K per year
NASA IPY Program:	FY2007 - 2009, $135K per year for Wu
NASA MeaSure Program:	FY2008 – 2012, 0-0.2 FTE for Wu, PI: Zlotnicki

Pending Support

NASA ESI Program:	FY2009 - 2011, $200K per year
NASA ESI Program:	FY2009 - 2011, 0.25 FTE for Wu, PI: Gross

Surface Mass Variations and Data



$$\sigma(R_e,\vartheta,\varphi,t) = \sum_{n=1}^{\infty}\sum_{m=0}^{n}\sum_{q=c,s} M_{nmq}(t)Y_{nmq}(\vartheta,\varphi)$$

Signatures

- Gravity change
- Surface displacements
- Ocean Bottom Pressure (OBP) change
- Geocenter motion, Earth rotation
- Relative Sea Level

Uncertainty Reduction

- GRACE + N=1 + OBP
- Unimodular Optimal Point and Regional Averages
- Full Data Covariance Matrix (Correlation)
- More Realistic Quantitative A priori

Significance of Geocenter Motion

Effects of 1 mm Geocenter Motion on GRACE Mean Mass Change Determination

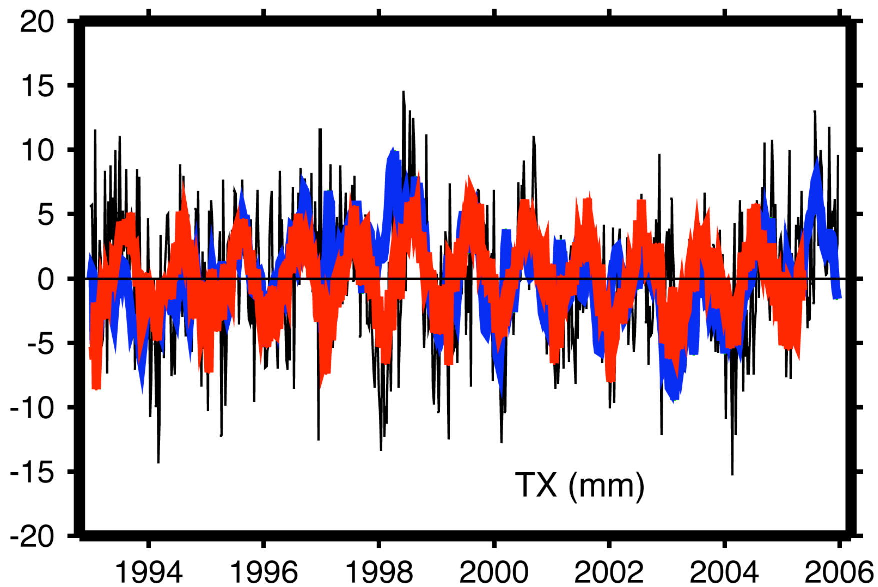
Region / Geocenter	Eustatic Sea Level mm	Mean Antarctic Ice mm	Mean Greenland Ice mm
X	**-0.46**	**0.07**	**1.26**
Y	**-0.24**	**0.49**	**-1.1**
Z	**-0.51**	**-5.6**	**5.6**

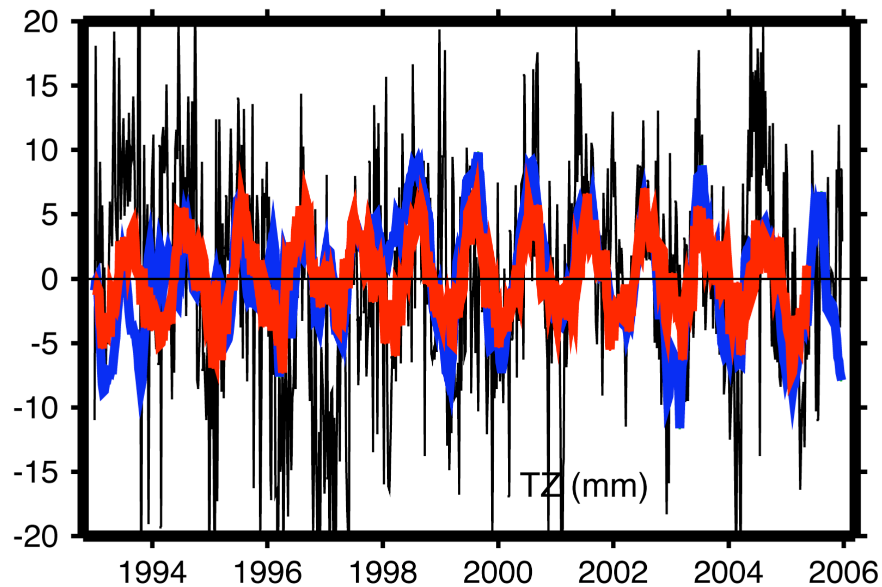
Satellite Tracking: $\vec{S}_{cm} - \vec{S}_{cn}$

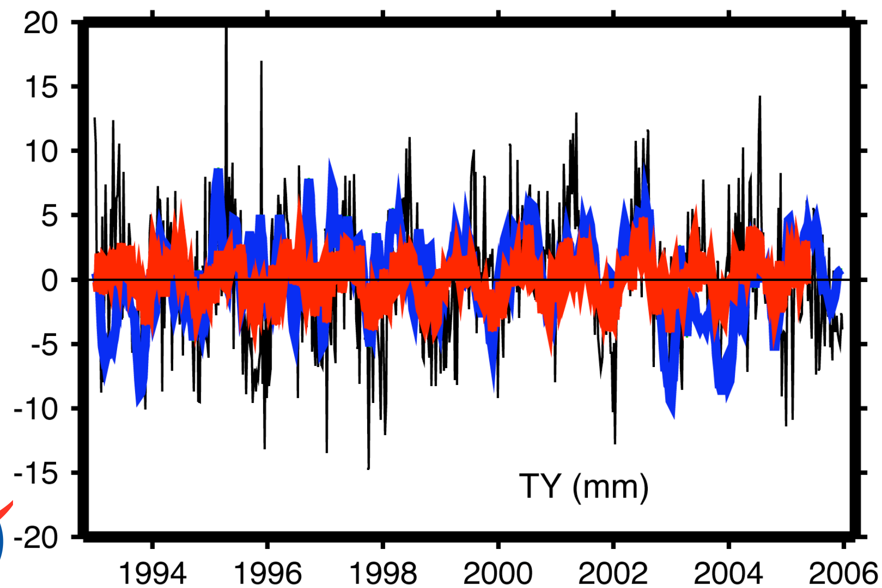
Inverse Determination: $G(\vartheta, \varphi, t) = \sum_{n=1} \sum_{mq} G_{nmq}(\vartheta, \varphi, p..) M_{nmq}(t)$

Present-trend and GIA: $\dot{G}(\vartheta, \varphi, t) = \sum_{n=1} \sum_{mq} G_{nmq}(\vartheta, \varphi, p..) \dot{M}_{nmq}(t) + \dot{G}^{\nu}$

Compare SLR, Climate Model and GPS/OBP Inversion







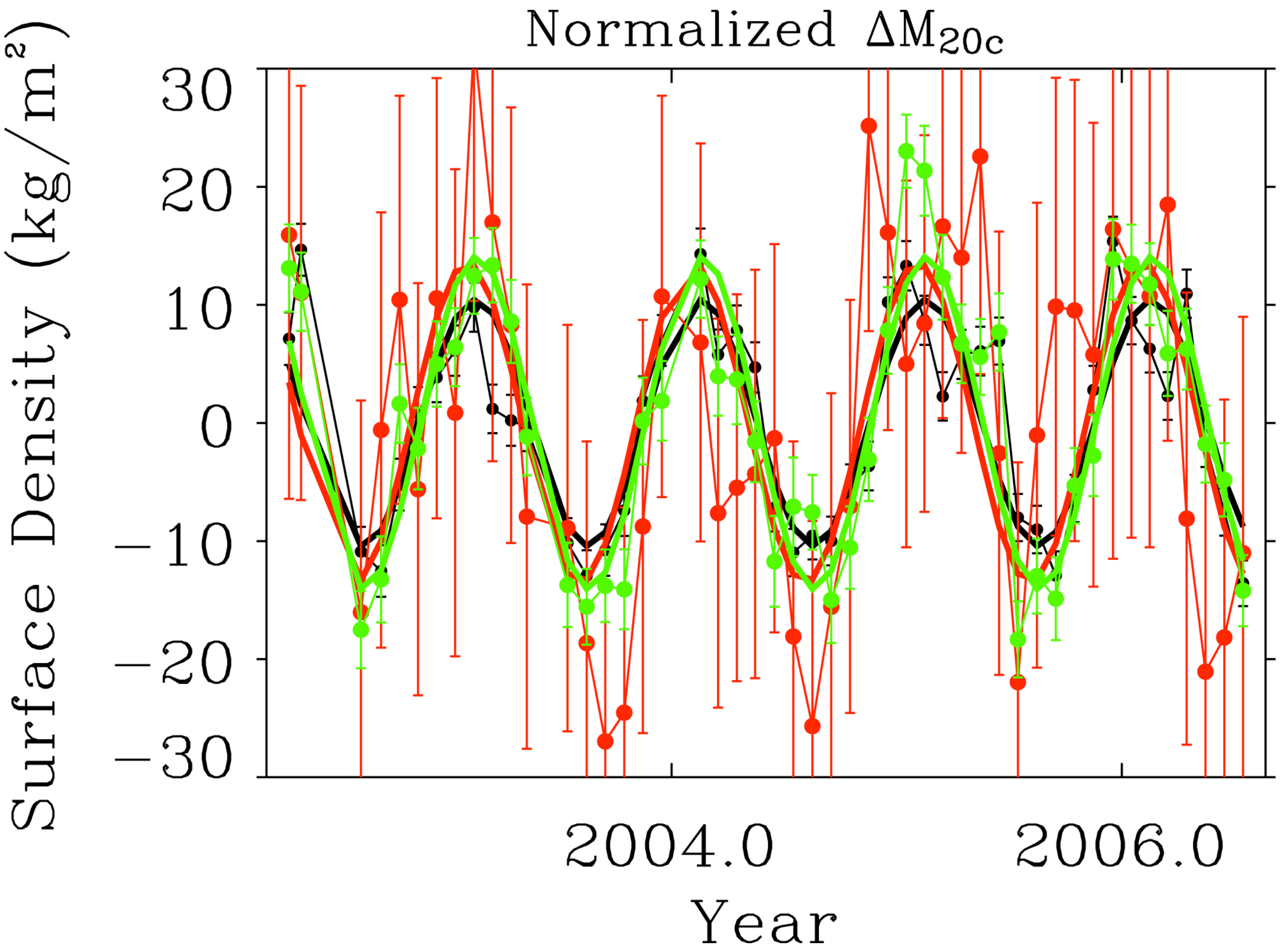
Imminent JGR Submission

— SLR from ITRF2005 Altamimi

— AOW Mass Model van Dam

— GPS/OBP Inversion

M_{20} Surface Density from GPS/OBP, SLR, GRACE



Simultaneous Global Inversion for Present-Day Trend + PGR
Dynamic Approach

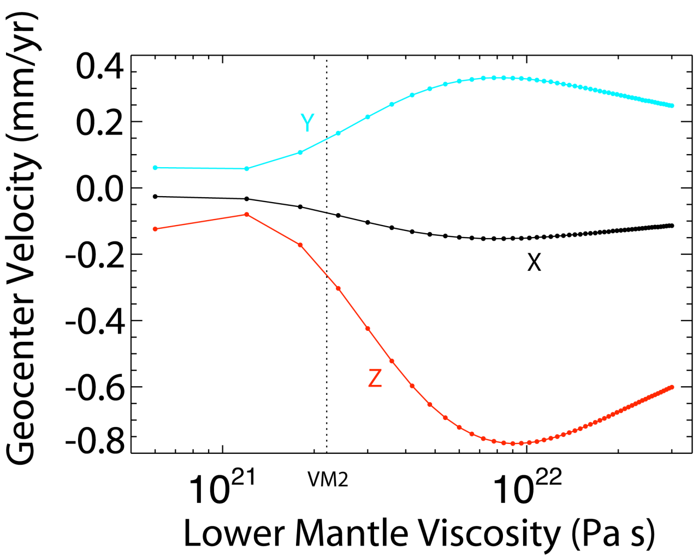
- Viscoelastic Earth Response
- Coupling of present-day trend and GIA signatures in modern data

$$\dot{V}_{lm} = \dot{V}_{lm}(\dot{M}_{lm}^{\text{CUR}}) + \dot{V}_{lm}^{\text{GIA}}(M_{\text{past}}, \tau, \nu)$$

- Combination of data with different physical origin for separation
- Combination of modern and historical data for time resolution
- Adapted viscoelastic Earth model (with n=1) + sea level equation solver

Effects of Ice Model
On GIA CM-CF

Model / Axis	ICE-5G/ IJ2005 mm/yr	ICE-5G mm/yr
X	-0.12	-0.08
Y	0.25	0.15
Z	-0.49	-0.26



Simultaneous Global Inversion for Present-Day Trend + PGR Kinematic Approach

- **Objectives**
  - Improve PGR and Present-day trend estimation with GRACE/GPS/OBP
  - Separate estimation of geocenter velocities due to present trend and GIA
- **Data Equations:**

Geocentric Velocity:

$$\dot{\vec{\mathbf{s}}} = \sum_{n=1}^{\infty}\sum_{mq}\Big((a_n \dot{M}_{nmq} + b_n \dot{M}^{\nu,k}_{nmq})\, Y_{nmq}\hat{\mathbf{e}}_r + (c_n \dot{M}_{nmq} + d_n \dot{M}^{\nu,l}_{nmq})(\partial_\vartheta Y_{nmq}\hat{\mathbf{e}}_\vartheta + l'_n \frac{1}{\sin\vartheta}\partial_\varphi Y_{nmq}\hat{\mathbf{e}}_\varphi)\Big)$$

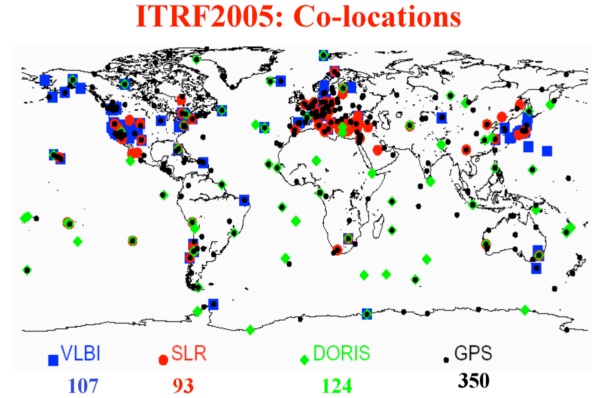
$$-\frac{4\pi}{\sqrt{3}}\frac{a^3}{M_E}\left(\dot{M}_{11c}\hat{\mathbf{e}}_x + \dot{M}_{11s}\hat{\mathbf{e}}_y + \dot{M}_{10c}\hat{\mathbf{e}}_z\right) + \vec{\boldsymbol{\omega}} \times \vec{\mathbf{X}}_{\mathbf{i}}$$

Ocean Bottom Pressure: $\dot{P} = gO(\vartheta,\varphi)\dot{M}$

Geoid: $\dot{N} = \sum_{n=2}^{\infty}\sum_{mq}(f_n \dot{M}_{nmq} + g_n \dot{M}^{\nu,k}_{nmq})\, Y_{nmq}$

- **Method to Separate Geocenter Velocities due to Present-Trend and GIA**

Secular Geocenter Motion and International Terrestrial Reference Frame Stability



- Geocenter CM = Datum of Satellite Tracking =? origin of the ITRF
  - What is the geocenter motion rate? 2 mm/yr in Z ?
  - How accurate is the rate determined? ±2 mm/yr ?
  - Not acceptable since mean sea level only rises 2-3 mm/yr !
- Major Problems of Current ITRF Realization
  - Secular Frame, not instantaneous – TRF needs to be specified at all times
  - Different techniques are not combined weekly – enormous loss of info
- New Method for ITRF Realization
  - SLR/VLBI/GPS/DORIS data weekly combination
  - Co-located sites moving together
  - Effects of non-secular motions