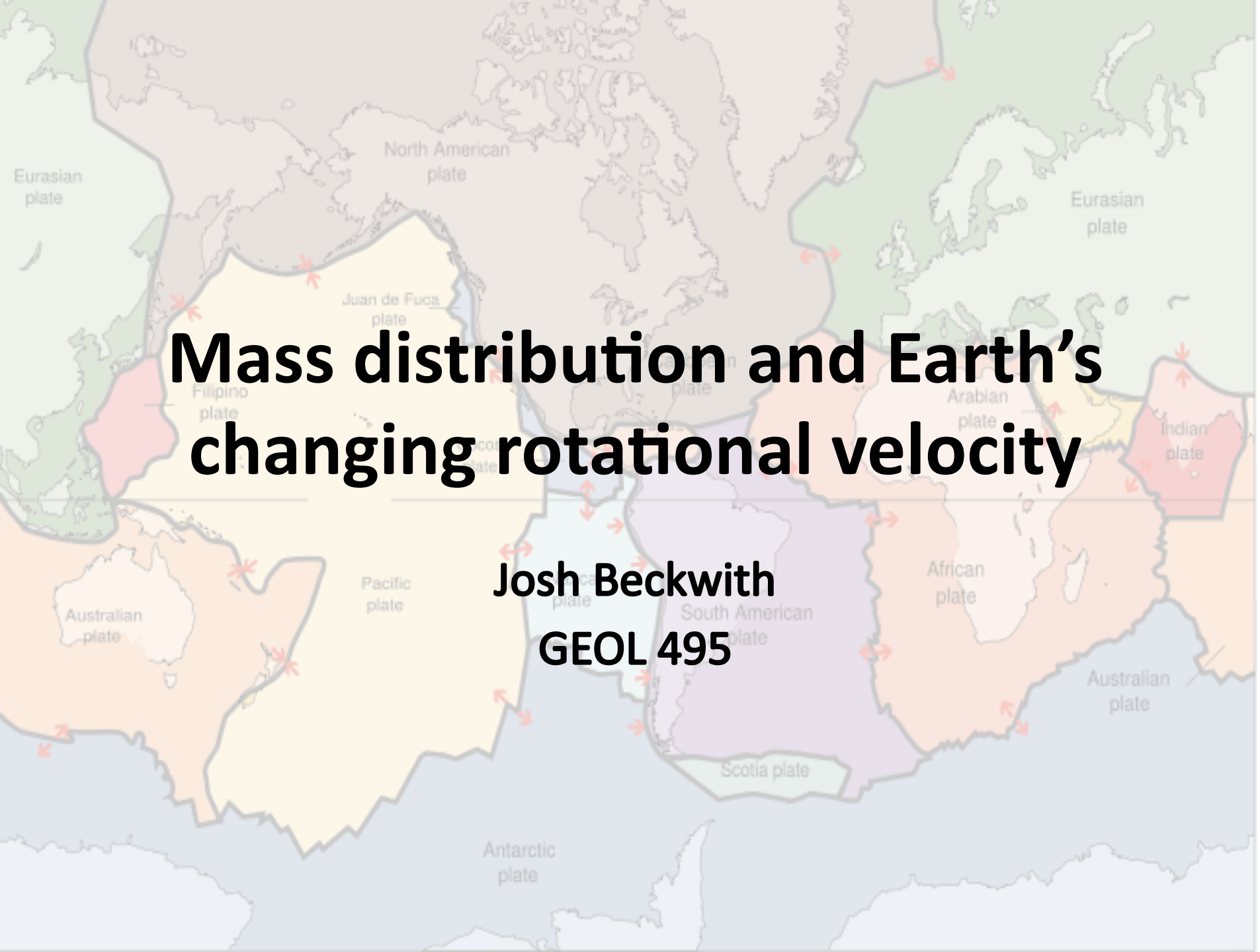
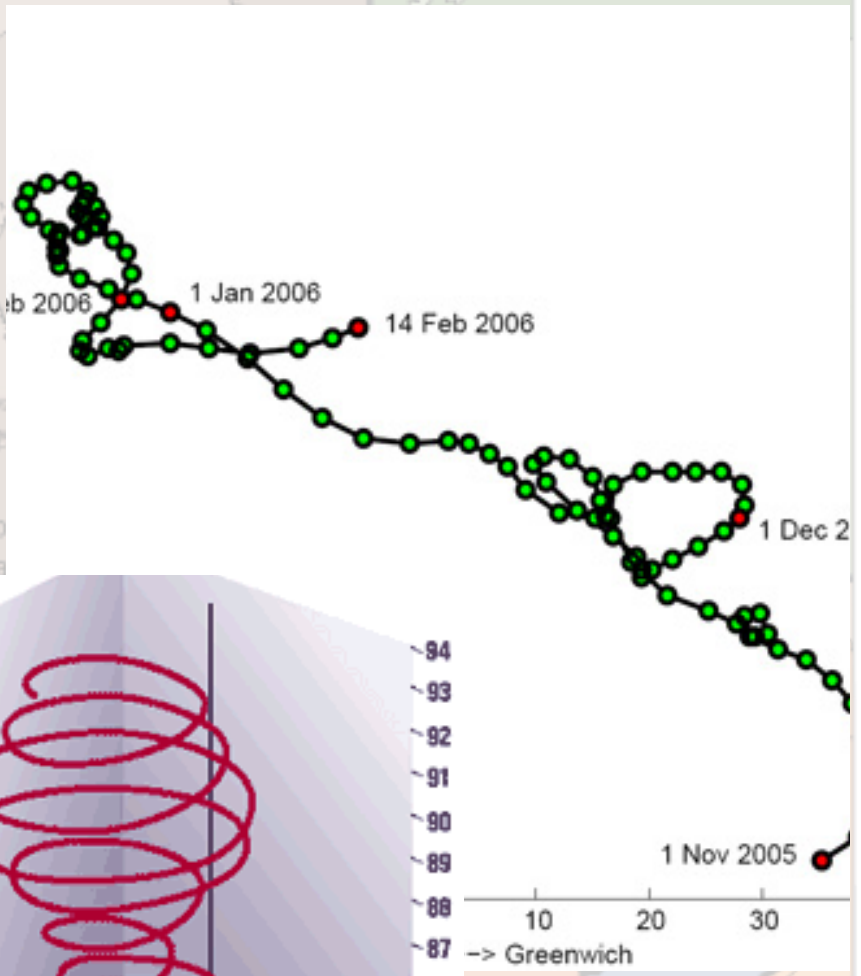


Mass distribution and Earth's changing rotational velocity

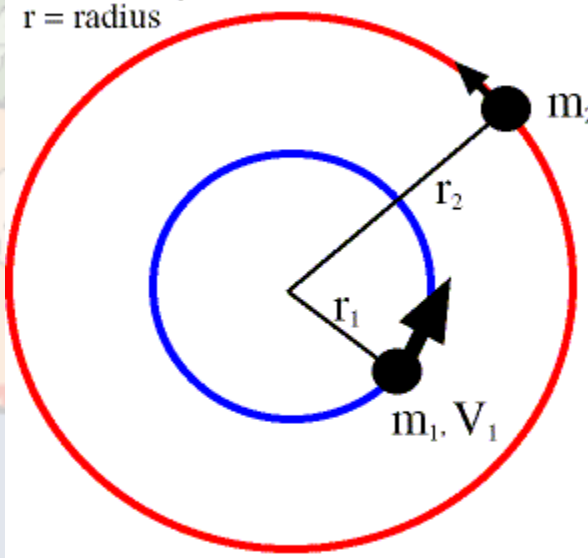
Josh Beckwith

GEOL 495

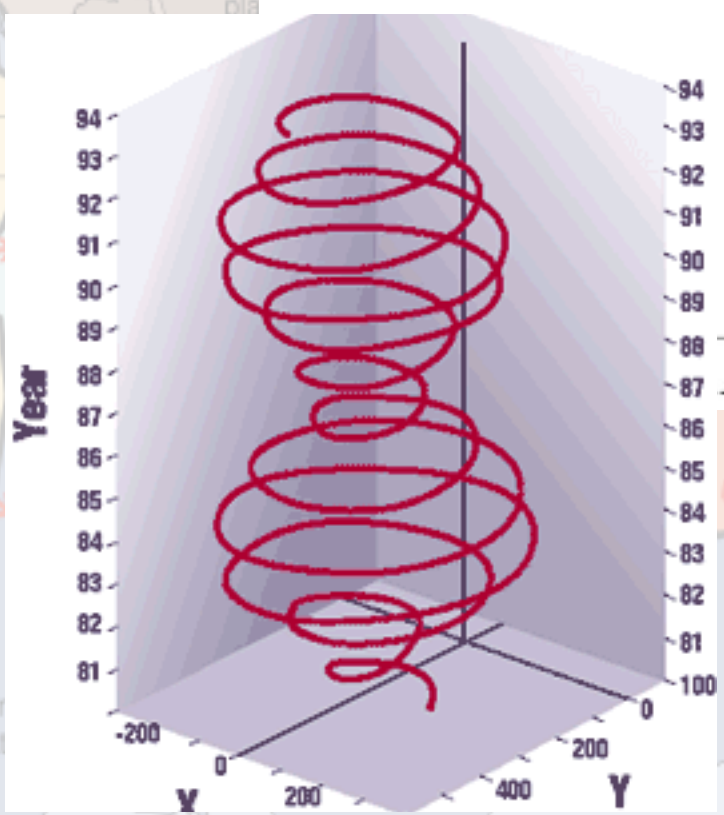
- Earth wobbles because center of mass (CM) is on different axis than rotation
- Rotational axis in space is controlled entirely by interplanetary interactions
- Any mass redistribution on planet relocates location of CM



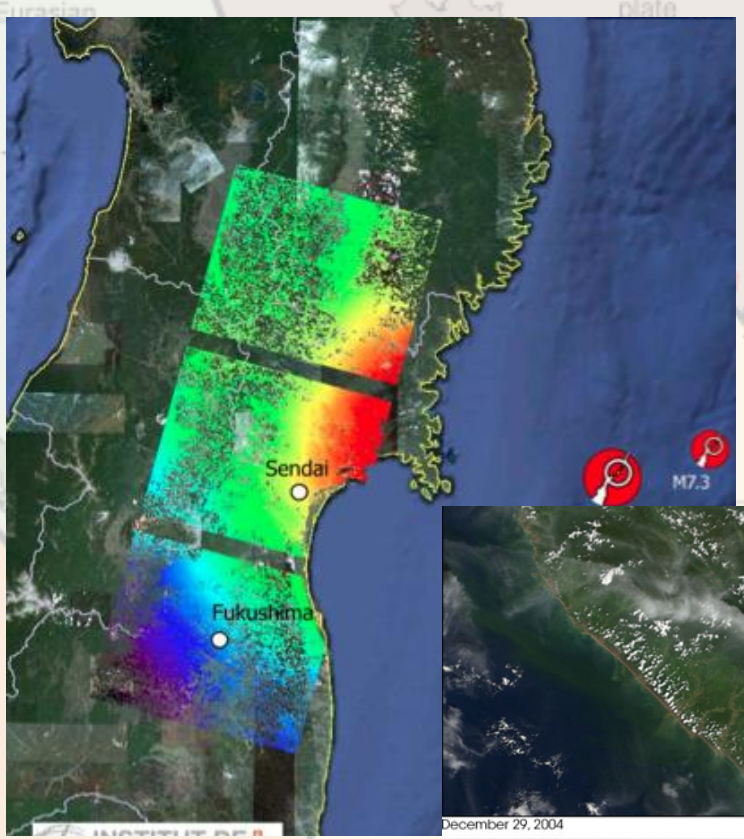
Angular momentum = mvr
m = mass
v = velocity
r = radius



Conservation of angular momentum
$m_1 v_1 r_1 = m_2 v_2 r_2$



Coseismic Deformation



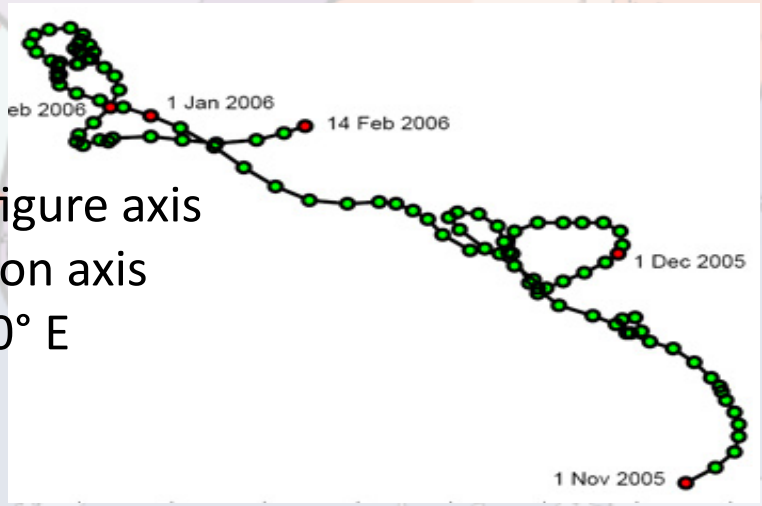
December 26, 2004

December 29, 2004

January 1, 2004

History

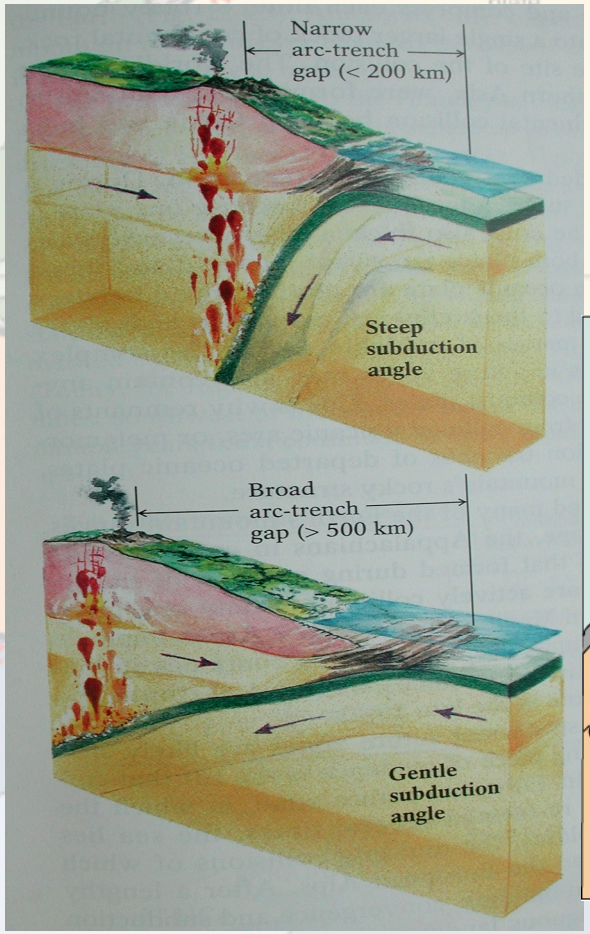
Location	Date	Magnitude	Change in LOD	CM axis shift
Chile	2010-2-27	8.8	-1.26 µs	8 cm
Sumatra	2004-12-26	9.1	-6.8 µs	7 cm
Japan	2011-3-11	8.9-9.0	-1.8 µs	17 cm
Indonesia	2004*	9.0*	-2.68 µs	2.5 cm*
Chile	1960-5-22	9.5	-8.0 µs	2 cm*

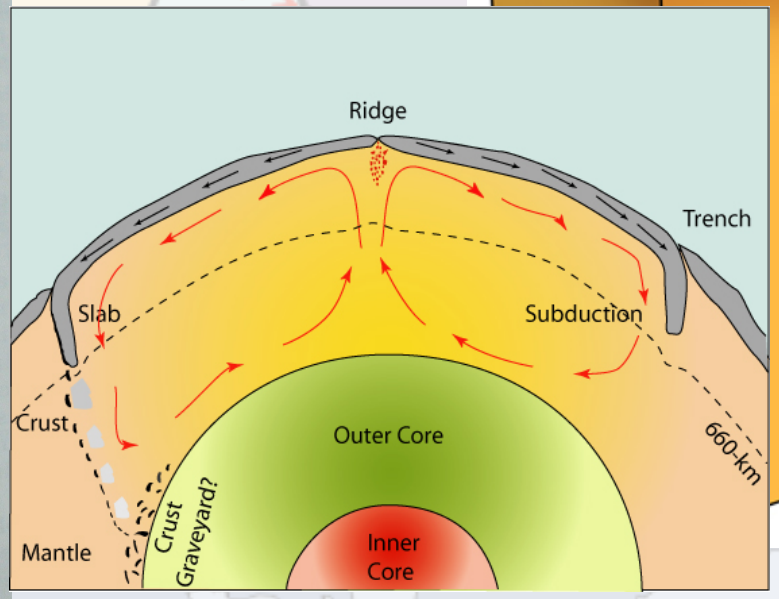


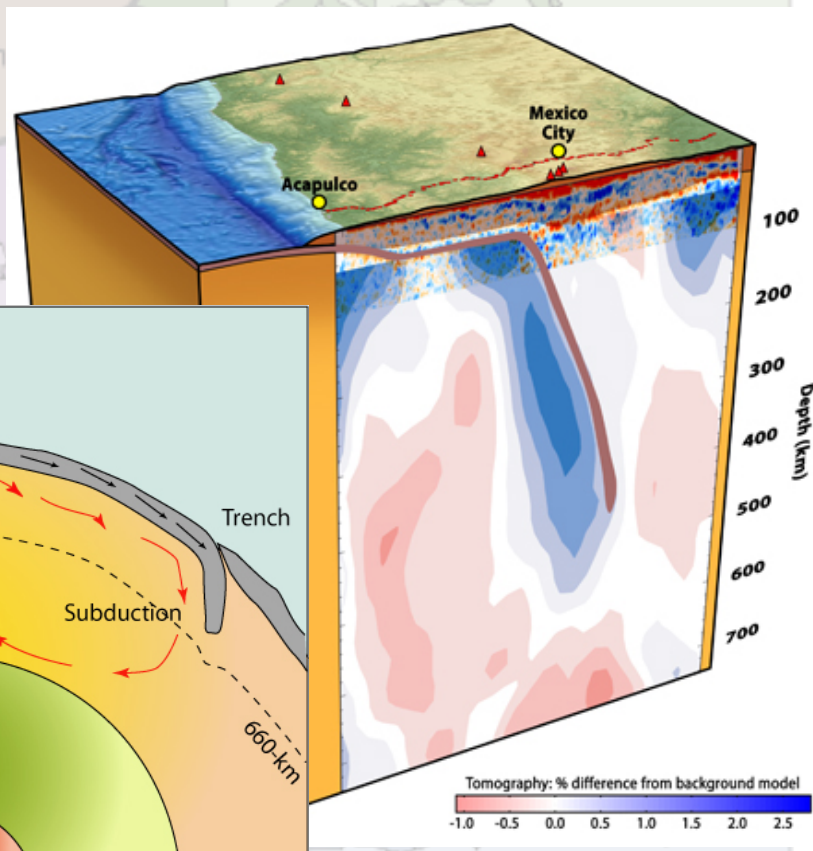
- CM axis shift* in Pole Position, not figure axis
- Figure axis ~ 10 m offset from rotation axis
- Trend in figure axis movement ~ 140° E
- 24 hours = 86,400,000 µs
- LOD varies ~ 1,000 µs per year

Magnitude does not indicate change in CM, also independent of change in LOD

- Subduction angle, and rupture depth have significant effect on mass relocation
- Steep subduction produces slab interaction at core-mantle boundary, site of rotational effects

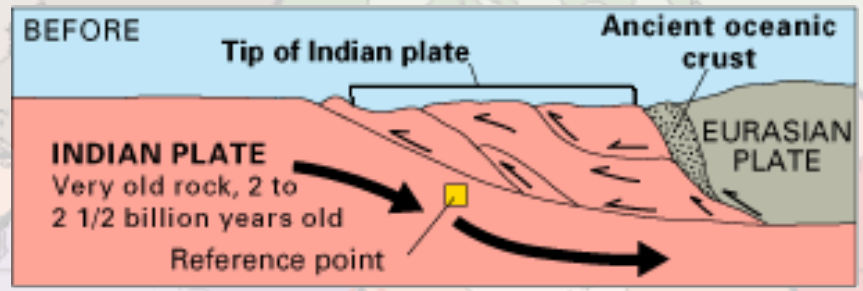


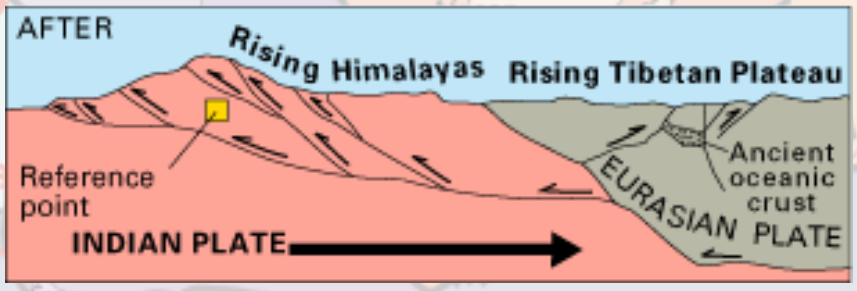


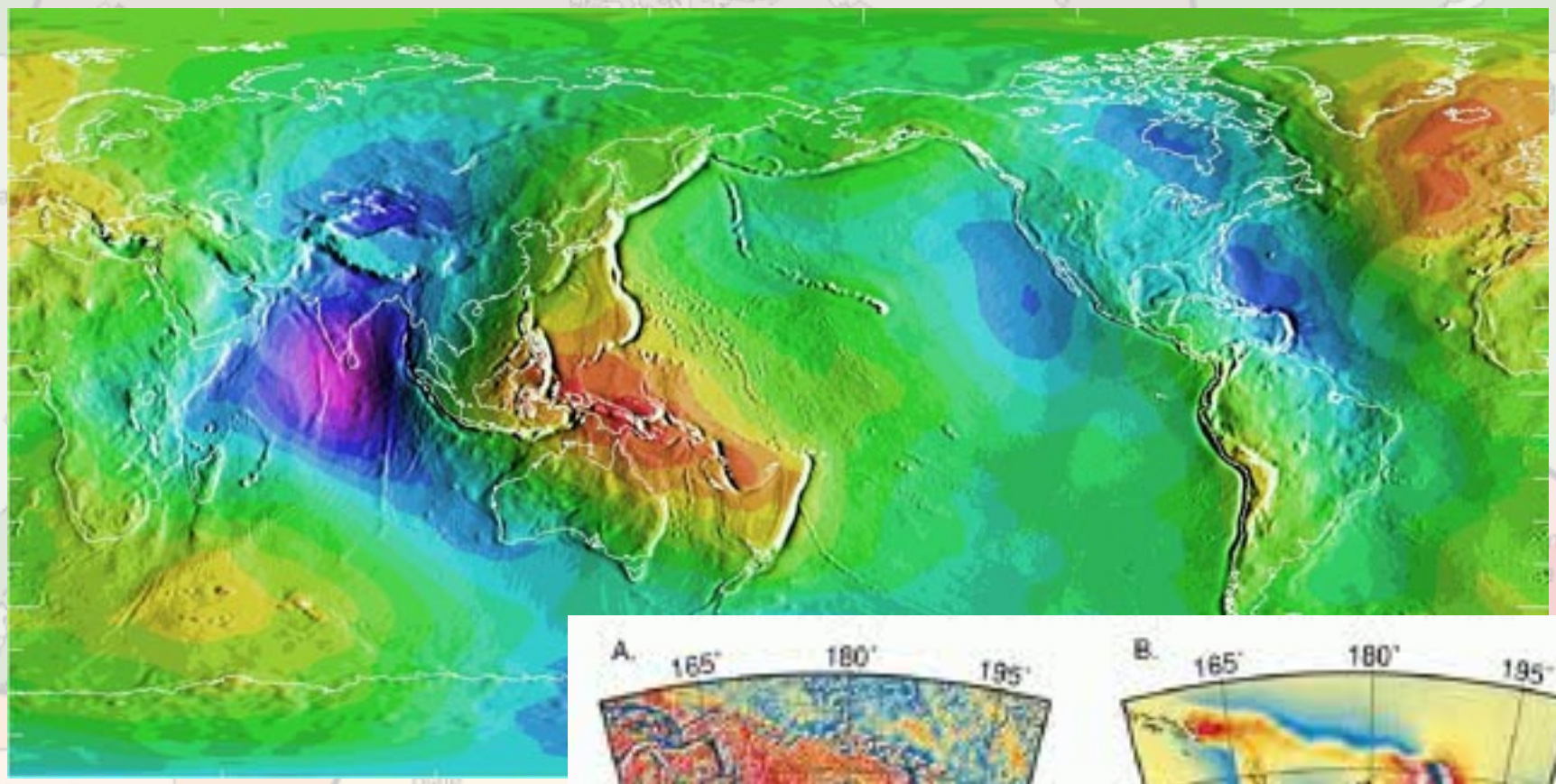


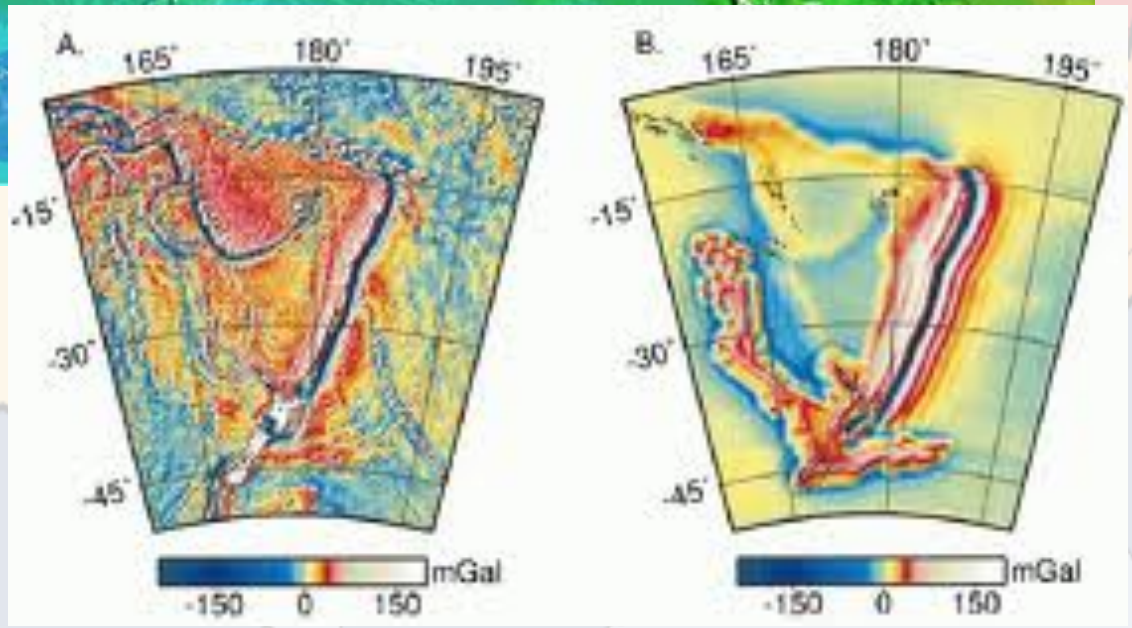
Magnitude does not indicate change in CM, also independent of change in LOD

- Shallow, continental subduction (convergence) relocates mass that tends to be less dense than oceanic crust
- Continental subduction has less effect on redistribution of CM





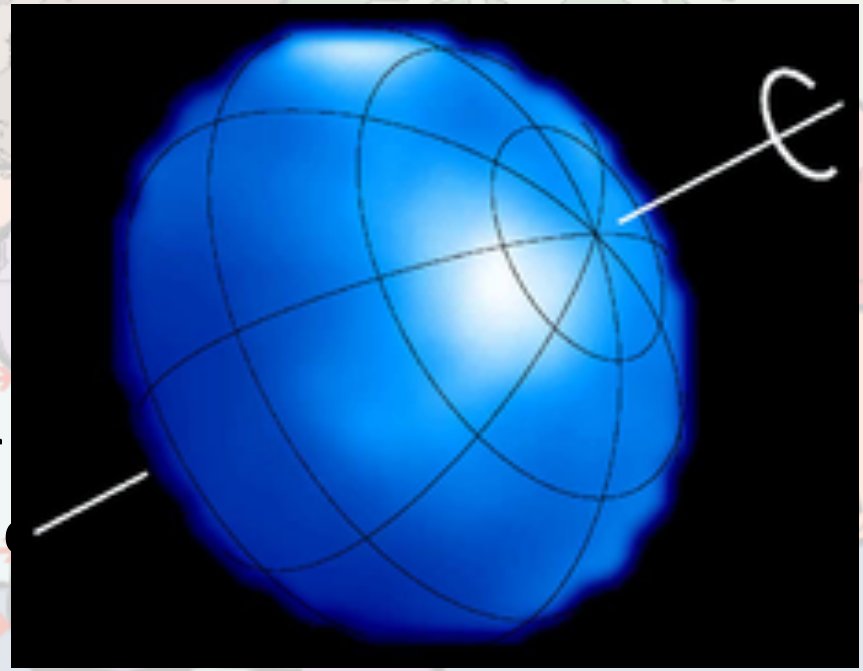




- Plate convergence produces clear signal in geoid and gravity anomaly

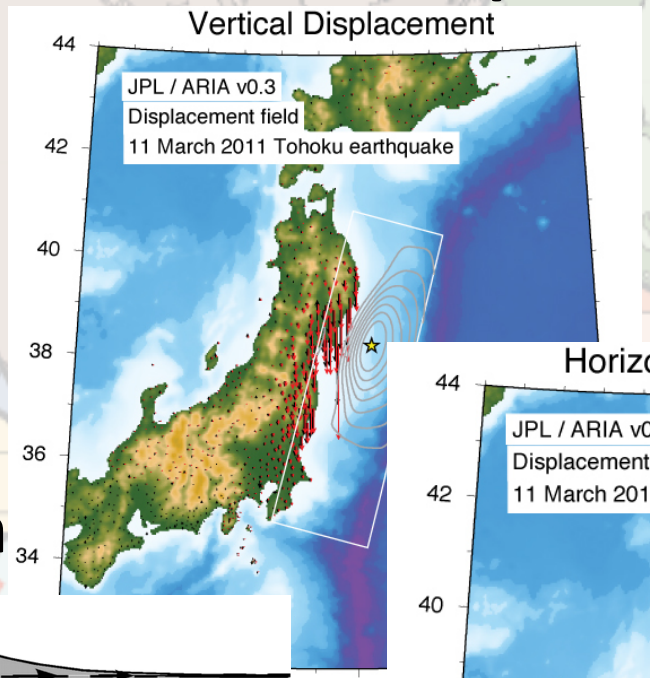
Magnitude does not indicate change in CM, also independent of change in LOD

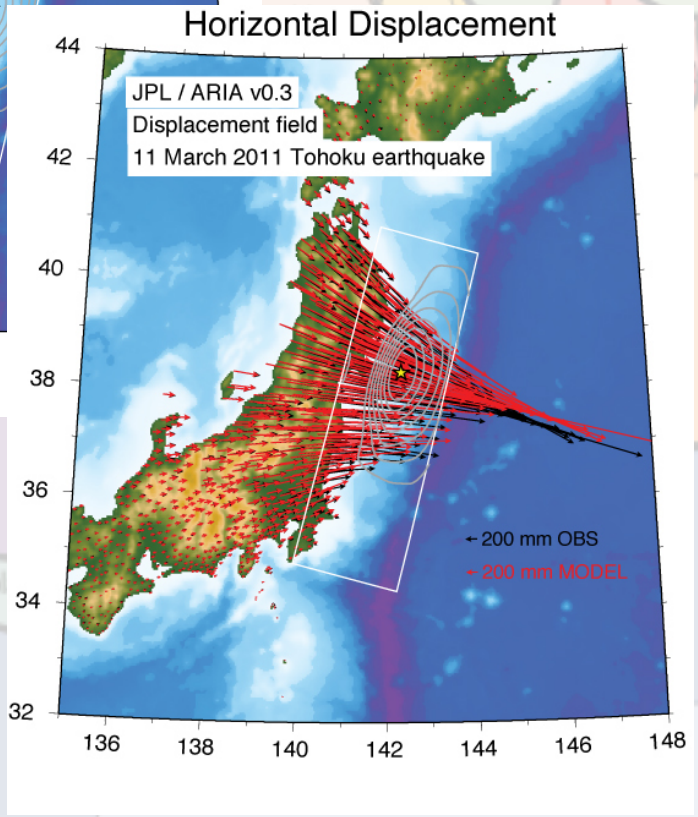
- Oblateness of reference ellipsoid, and geoid, control moment of inertia
- Coseismic displacement moves ellipsoid toward less oblateness
- Latitude of event has greater effect on LOD than magnitud
- Mid-latitude events have greatest effect

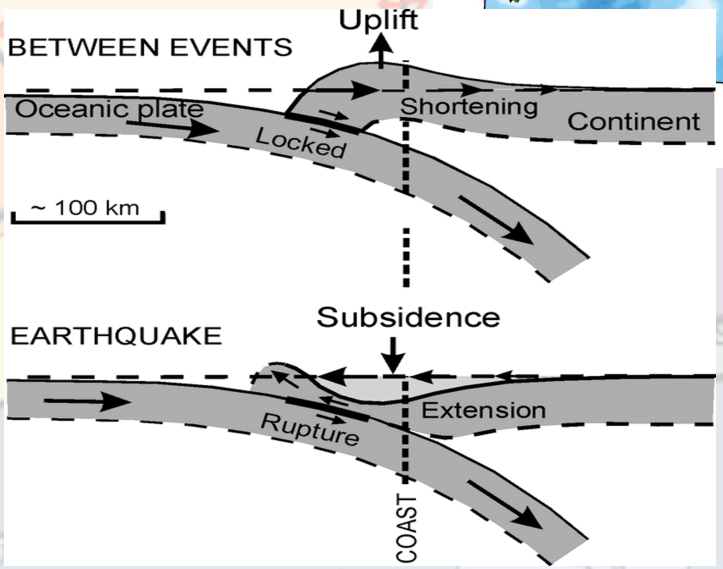


Shift in figure axis vs. displacement

- Japan earthquake shifted figure axis ~17 cm
- Coseismic displacement of Japan ~2.4 m





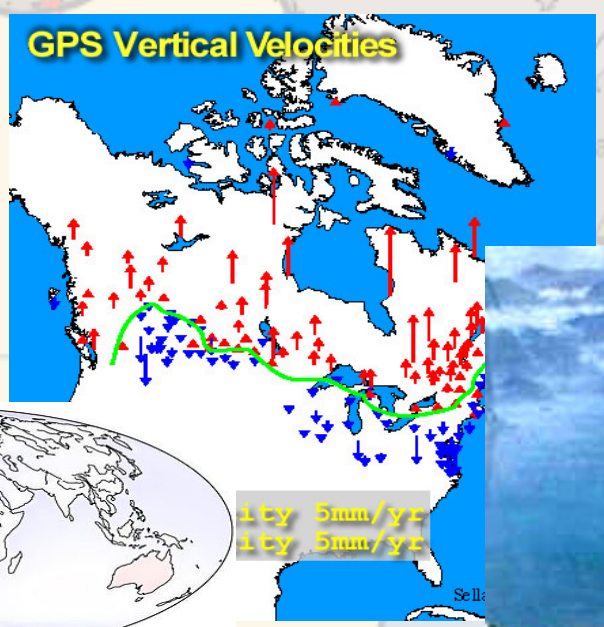


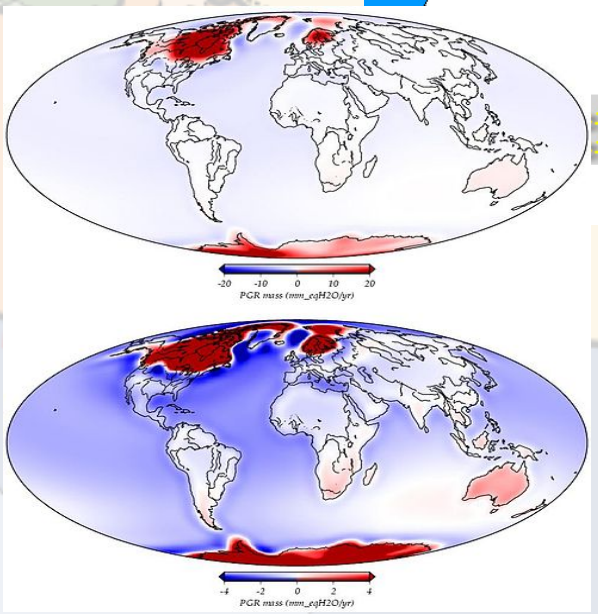
Long period changes to LOD

- Changes in moment of inertia at CMB
- Post glacial rebound
- Post-seismic deformation augments coseismic
- Pre-seismic deformation is slow counteraction
- Mass transport, at surface and depth
- Seasonal mass changes in atmosphere, cryosphere, hydrosphere, and on land
- Long period tidal effects
- Average annual total change in LOD ~ 1 my^{-1}

Long period changes to LOD

- Post glacial rebound ~10 mmy^{-1}, -0.7 μs(cy)$^{-1}$ LOD, 1° ma^{-1} shift in figure axis





- Three Gorges dam will hold 40 km^3, +0.06 μs LOD, 2.0 cm pole shift

Observing changes in LOD

- GRACE can **observe** long period changes
- Short period, coseismic displacement has small effect that is **calculated**
- Geoid is effected by mass distribution, changing with shifts in figure axis
- Free oscillating harmonics change with material distribution

Summary

- Coseismic deformation redistributes mass on a short time period, lowering Earth's moment of inertia and increasing rotational velocity
- All other mass shifts produce greater change, but both positive and negative
- Greatest seismic effects on LOD occur when slab interacts with CMB