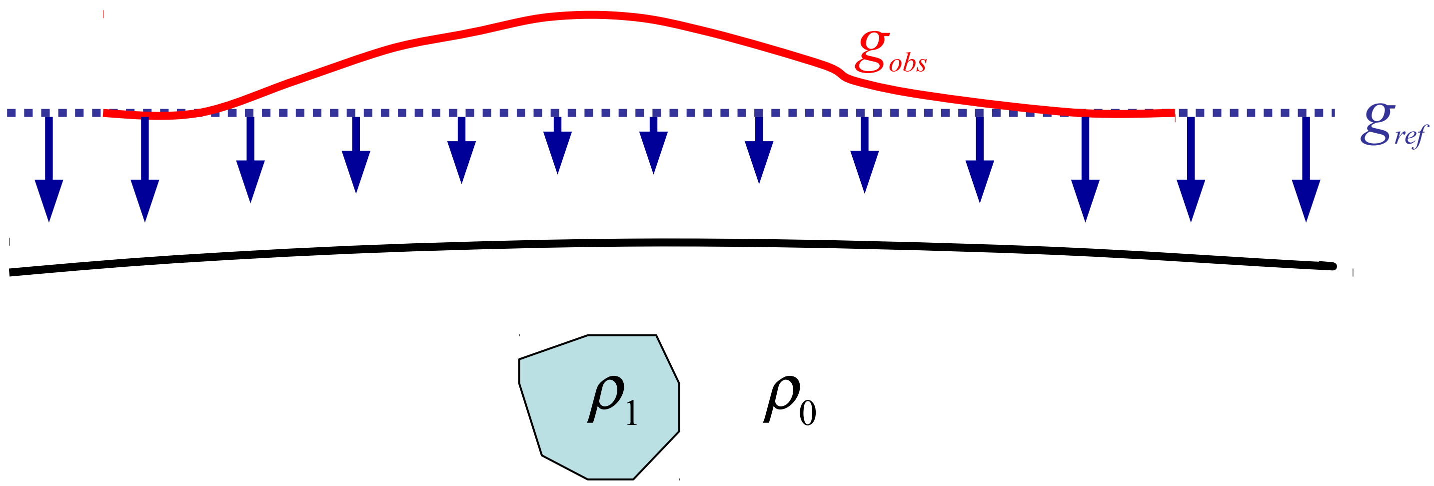
Gravity Anomalies

Density, ρ , is ***not*** radially symmetric in the Earth:
so $\vec{g}$ is ***neither uniform nor constant*** !!

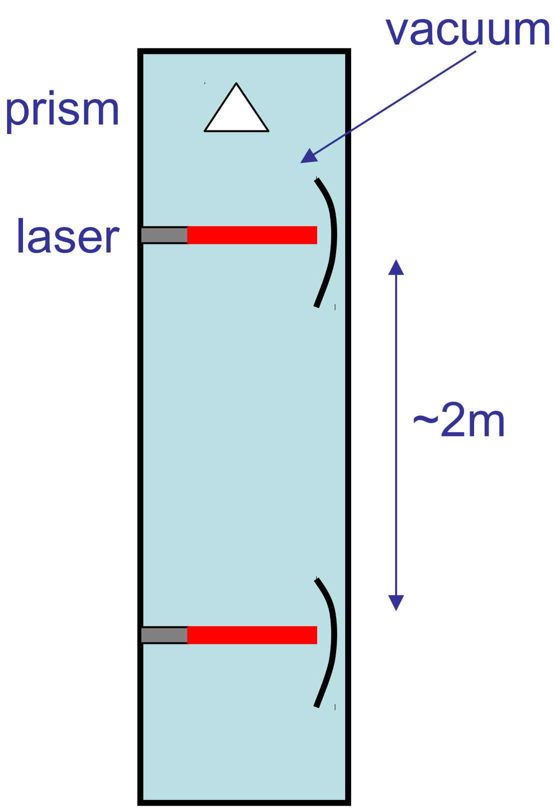
Gravity methods look for ***anomalies***, or perturbations, from a reference value of $\vec{g}$ at the Earth's surface:



$\rho_1 < \rho_0$

Gravity Measurements:

I. ***Absolute Gravity***: Need at few reference stations
Measure the total field ⇒ time of a falling body



- Must measure time to $\sim 10^{-11}$ s; distance to $\sim 10^{-9}$ m for 1 μgal accuracy!
- Nevertheless this is the most accurate ***ground-based*** technique (to ~3 μgal)
- Disadvantages: unwieldy; requires a long occupation time to measure

Gravity Measurements:

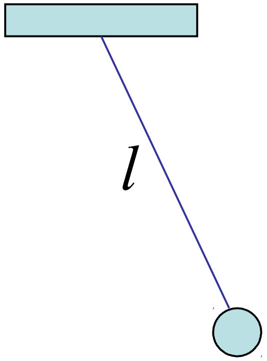
II. ***Relative Gravity*** :

Measures difference in $\vec{g}$ at two locations.

- ***Pendulum***: difference in period T:

$$T = 2\pi\sqrt{\frac{k}{g}} \approx 2\pi\sqrt{\frac{l}{g}}$$

Errors in timing of period $T \Rightarrow$ ~0.1 mgal

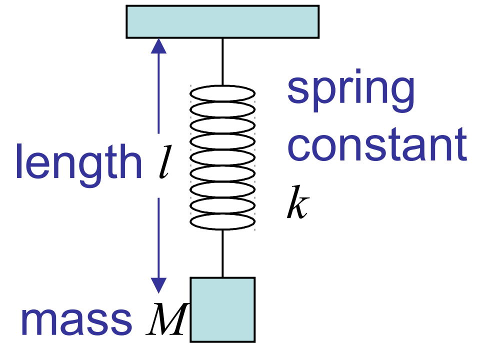


- ***Mass on a spring*** : $M\Delta g = k\Delta l$

or $\Delta g = k\Delta l/M$

Worden and Lacoste-Romberg Gravimeters (“zero-length” spring)

Errors ~ 6 μgal



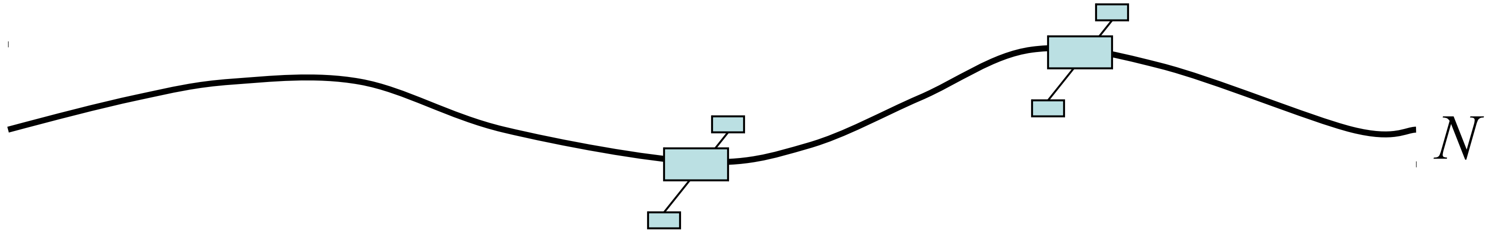
Gravity Measurements:

III. ***Satellite Gravity***:

Measure (from space) the height of an ***equipotential surface*** (called the ***geoid***, N) relative to a reference ellipsoid

- ***Ocean Altimetry***: Measure height of the ocean surface using radar or laser (e.g., SEASAT, JASON)

- ***Satellite Ranging***: Satellite orbits follow the geoid

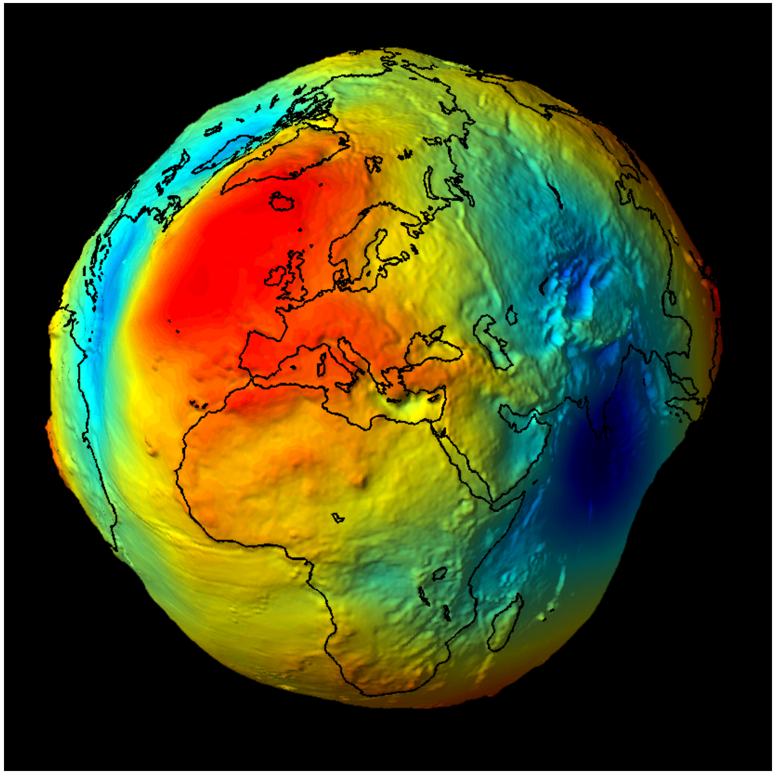


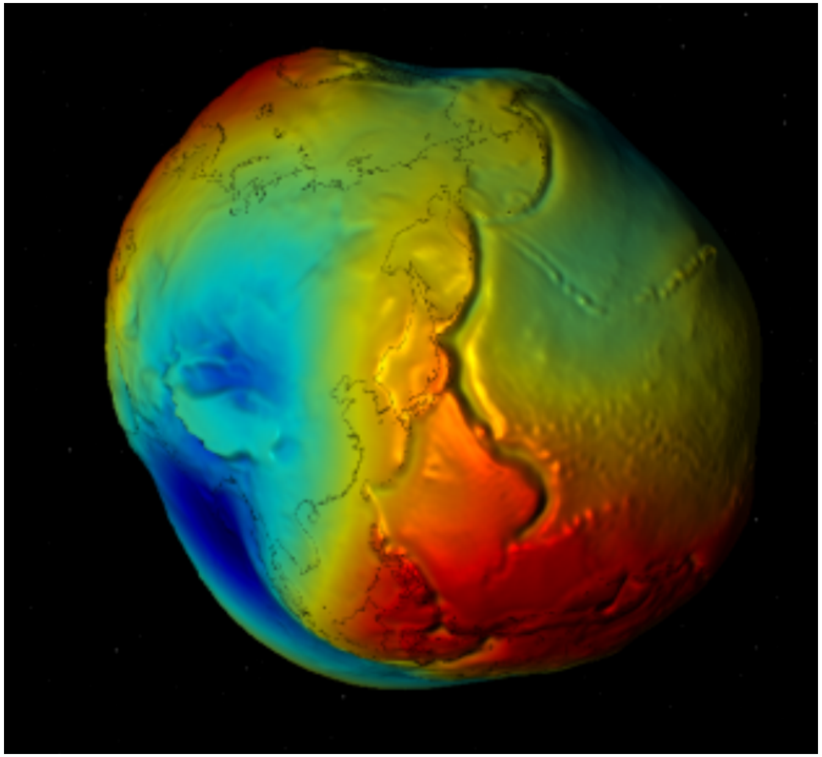
Measure orbits by ranging from the ground to the satellite or ranging between two satellites (e.g., GRACE)

Gravity Measurements:

III. *Satellite Gravity* :

Measure (from space) the height of an ***equipotential surface*** (called the ***geoid***, N) relative to a reference ellipsoid.

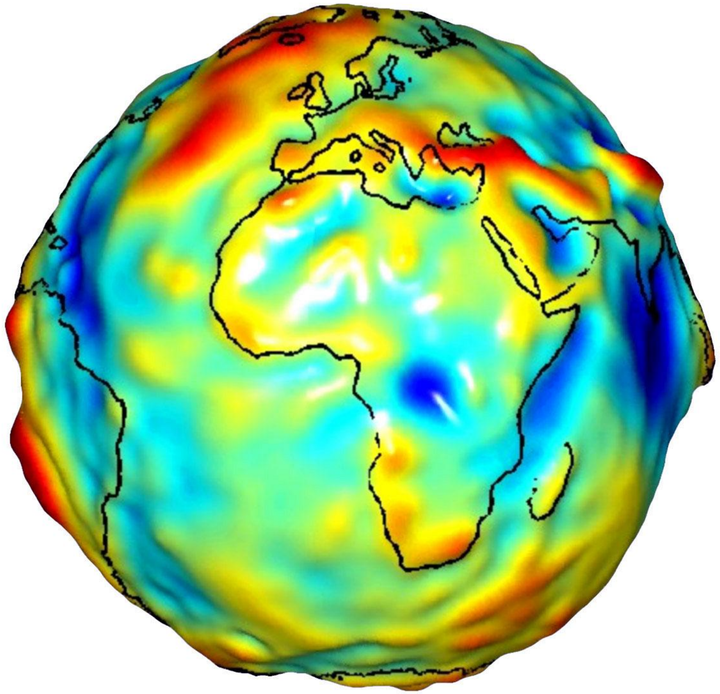


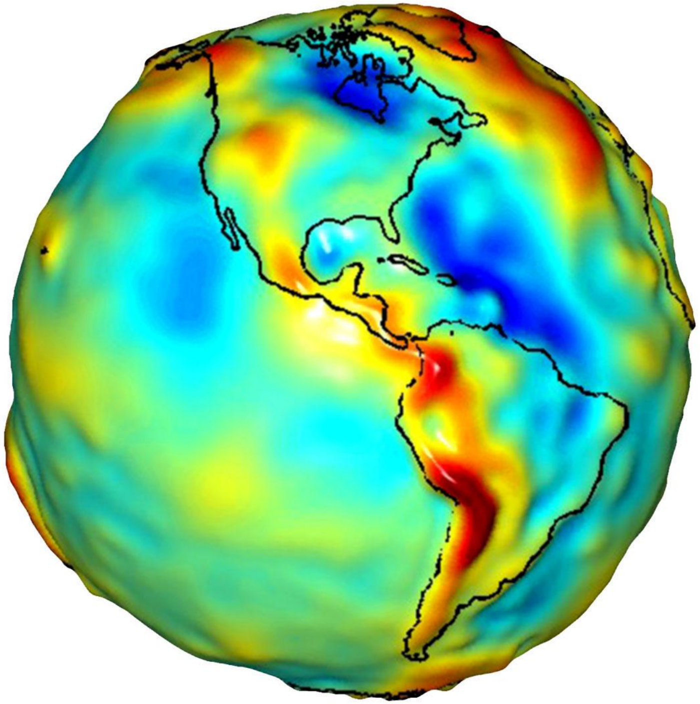


Gravity Measurements:

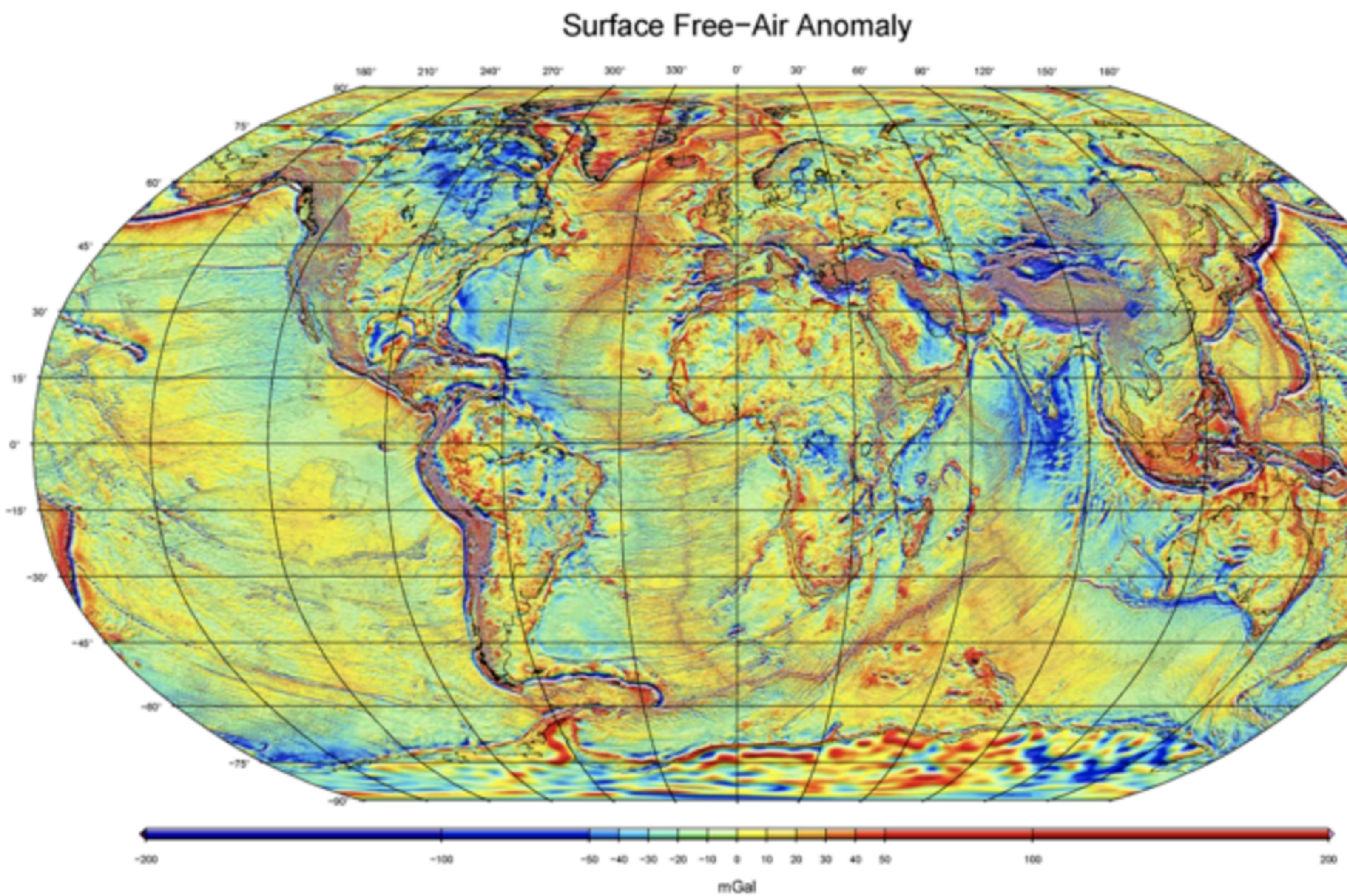
III. *Satellite Gravity* :

Gravity Anomalies from GRACE



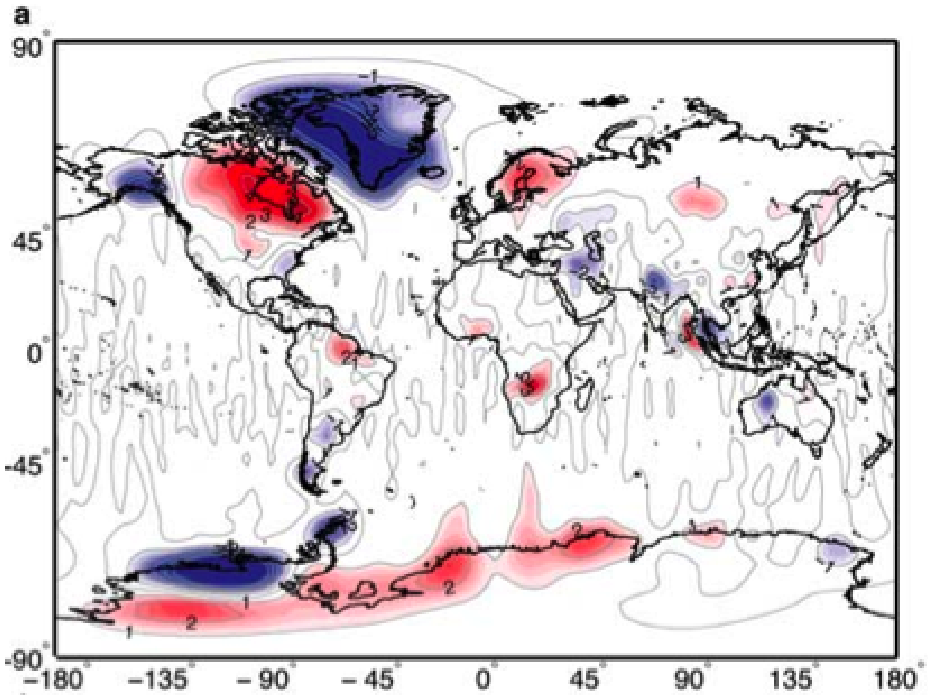


Global Free-Air Gravity Field from GRACE + GOCE + satellite altimetry + surface measurements…

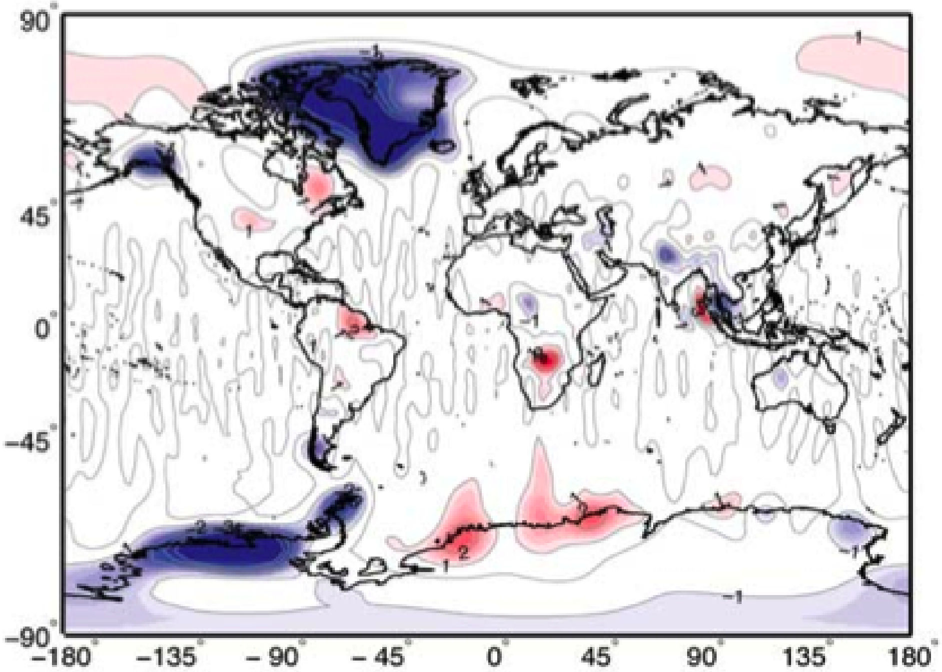


WGM2012 model from Bureau Gravimetríque International

GRACE Mass Trend 2003-2010: (Jacob et al., *Nature*, 2012)

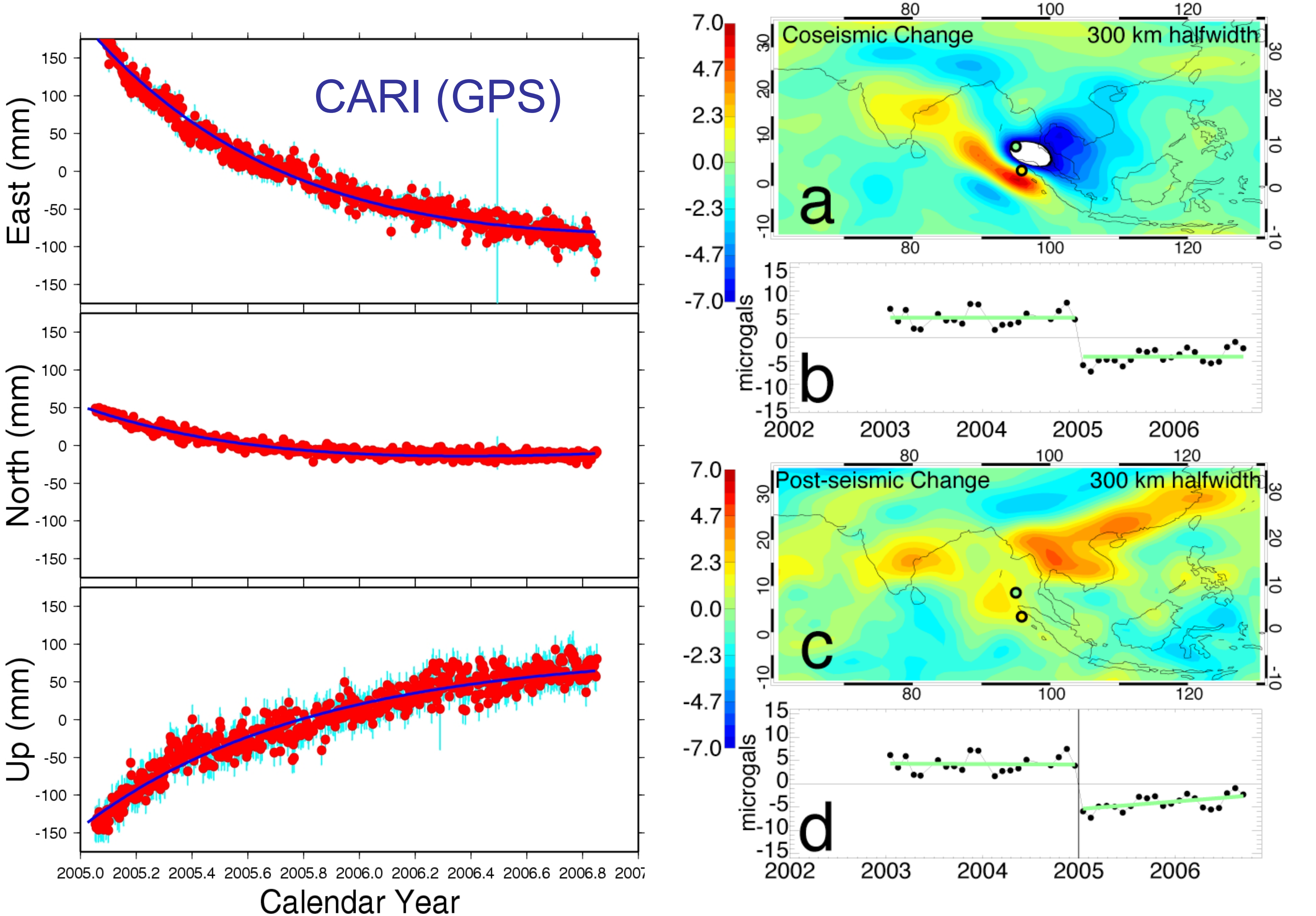


Total mass trend

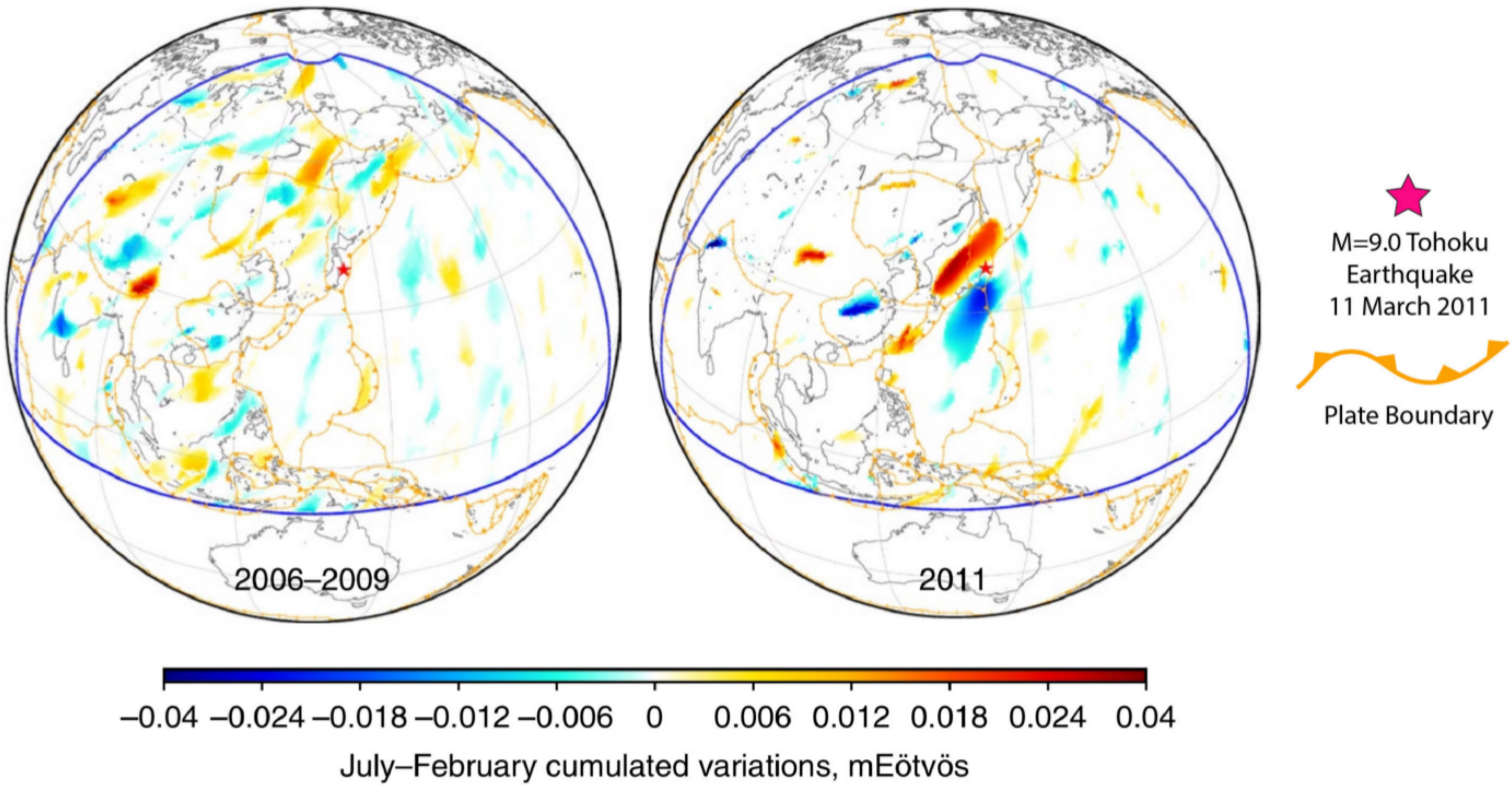


Corrected for solid Earth (i.e., the residual relates to hydrology + cryosphere)

GRACE detects deformation due to Mega-earthquakes (M>8)

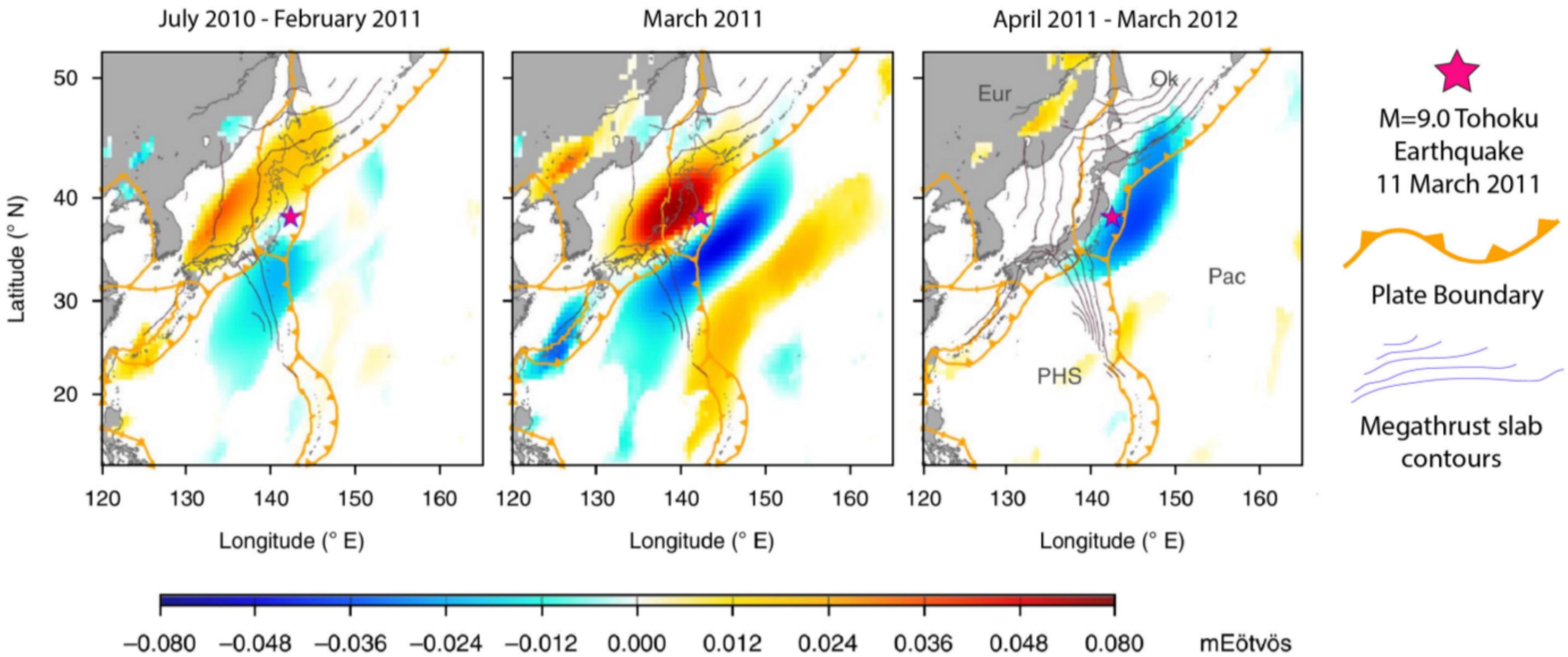


GRACE detects deformation due to Mega-earthquakes (M>8)



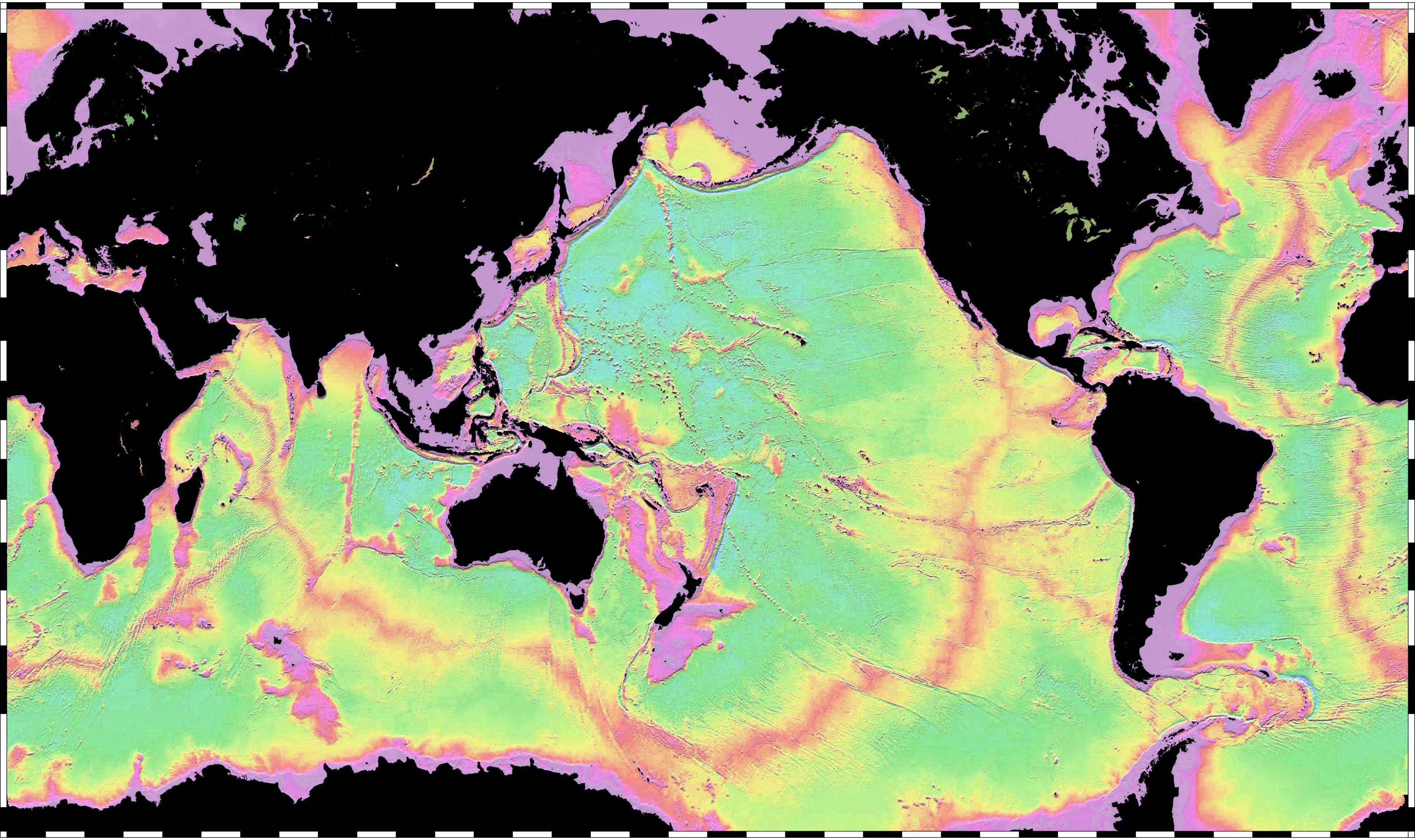
The left globe in this figure shows cumulated July–February anomalies stacked over 2006–2009. The right globe shows the zoomed out area from the first panel in the first figure, which is the time just prior to the M=9.0 Tohoku earthquake. (Figure from Panet et al., 2018)

GRACE detects deformation due to Mega-earthquakes (M>8)



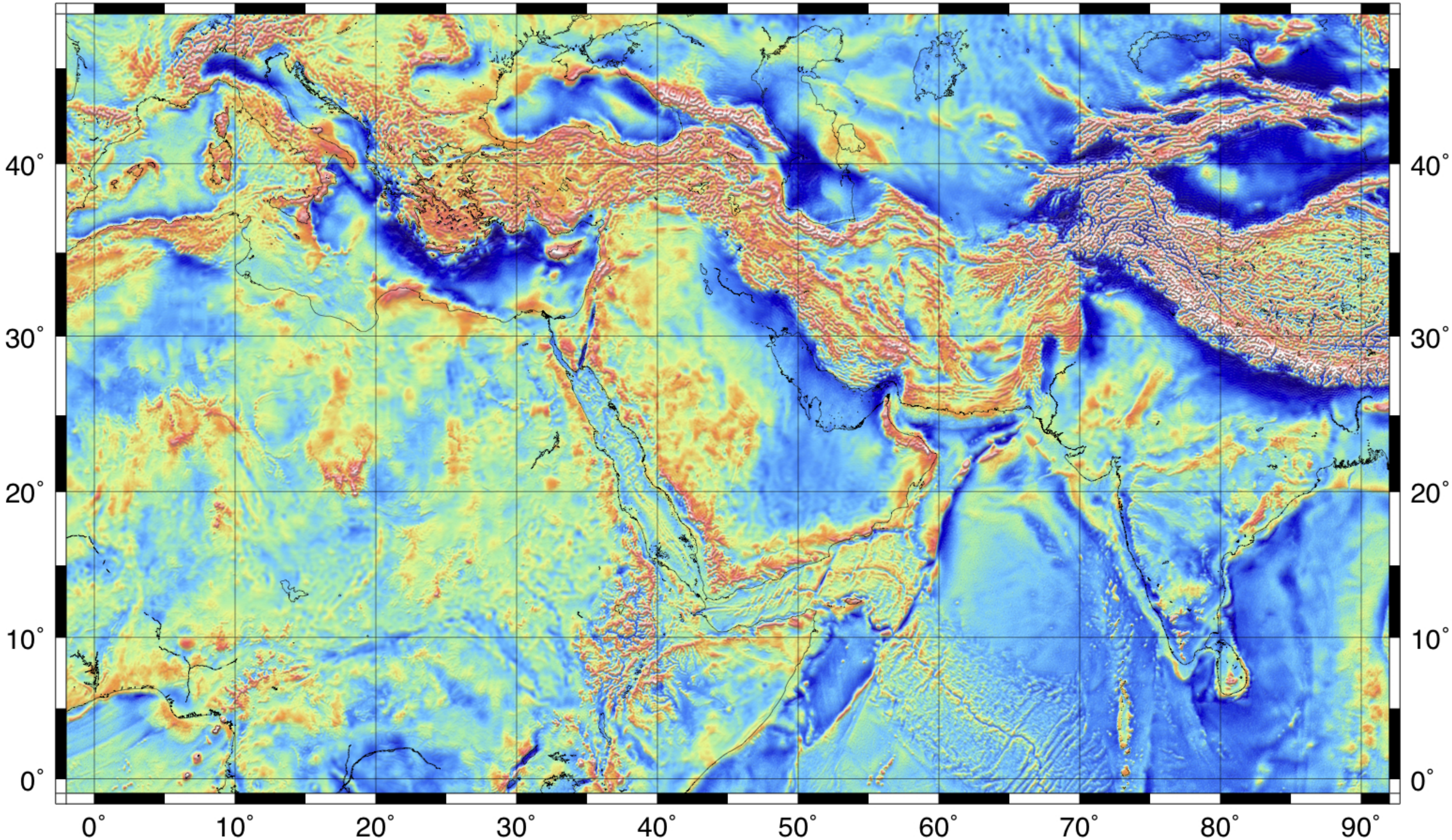
This map shows the gravitational gradient around the location of the Tohoku earthquake prior to, during, and after the quake. mEötvös are the gravitational gradient of the Earth, that is, the change in the gravitational acceleration vector from one point on the Earth's surface to another. 'Pac' is the Pacific Plate, 'PHS' the Philippine Sea plate, and 'Eur' the European plate. In the first two frames, the megathrust slab depth contours are every 200 km, while in the third, they are every 100 km. (Figure modified from Panet et al., 2018)

Example: Free Air Gravity from Satellite Ocean Altimetry



UCSD, Satellite Geodesy Pages: https://topex.ucsd.edu/marine_grav/mar_grav.html

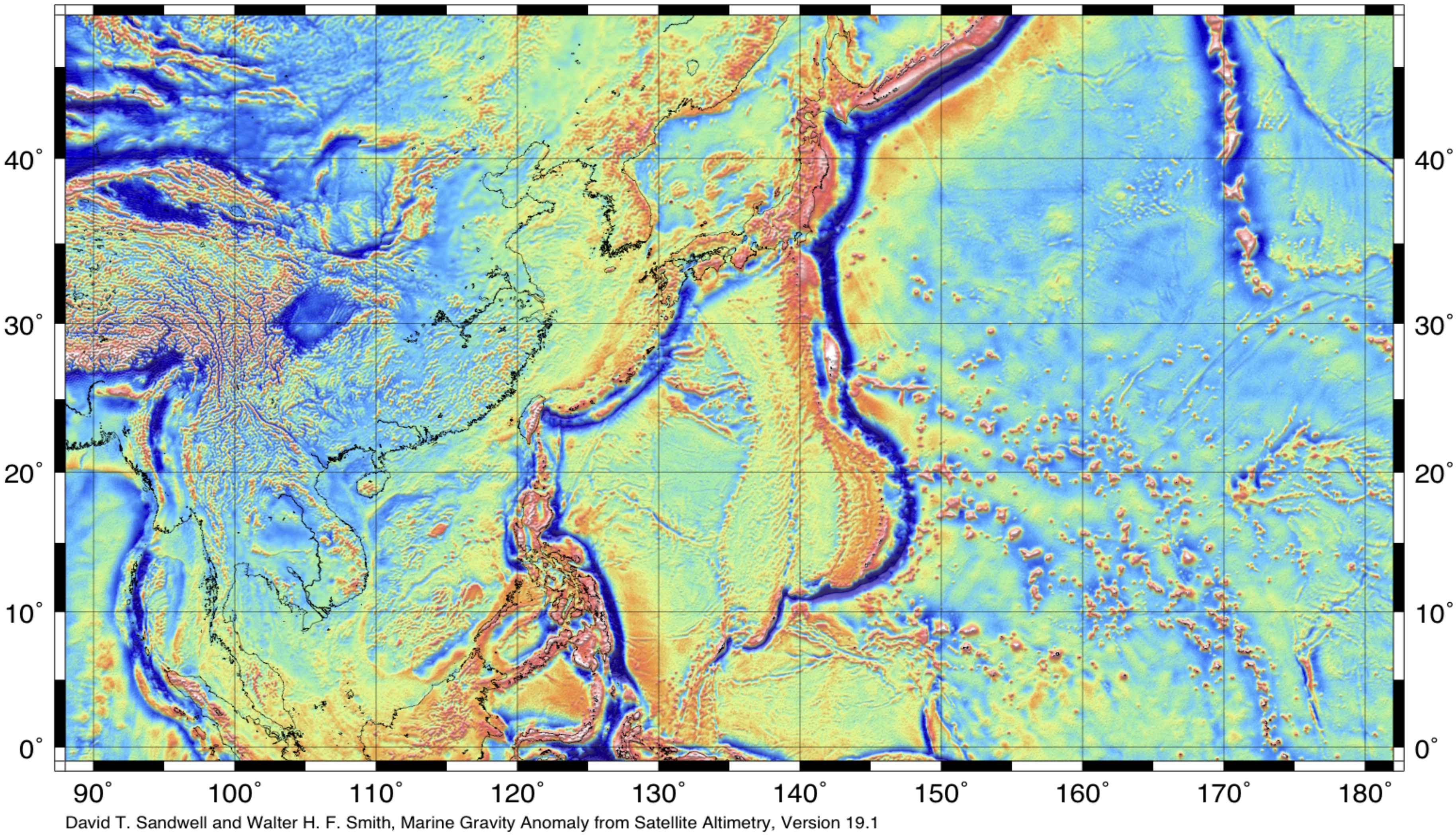
Details: East Africa, West & South Asia



David T. Sandwell and Walter H. F. Smith, Marine Gravity Anomaly from Satellite Altimetry, Version 19.1

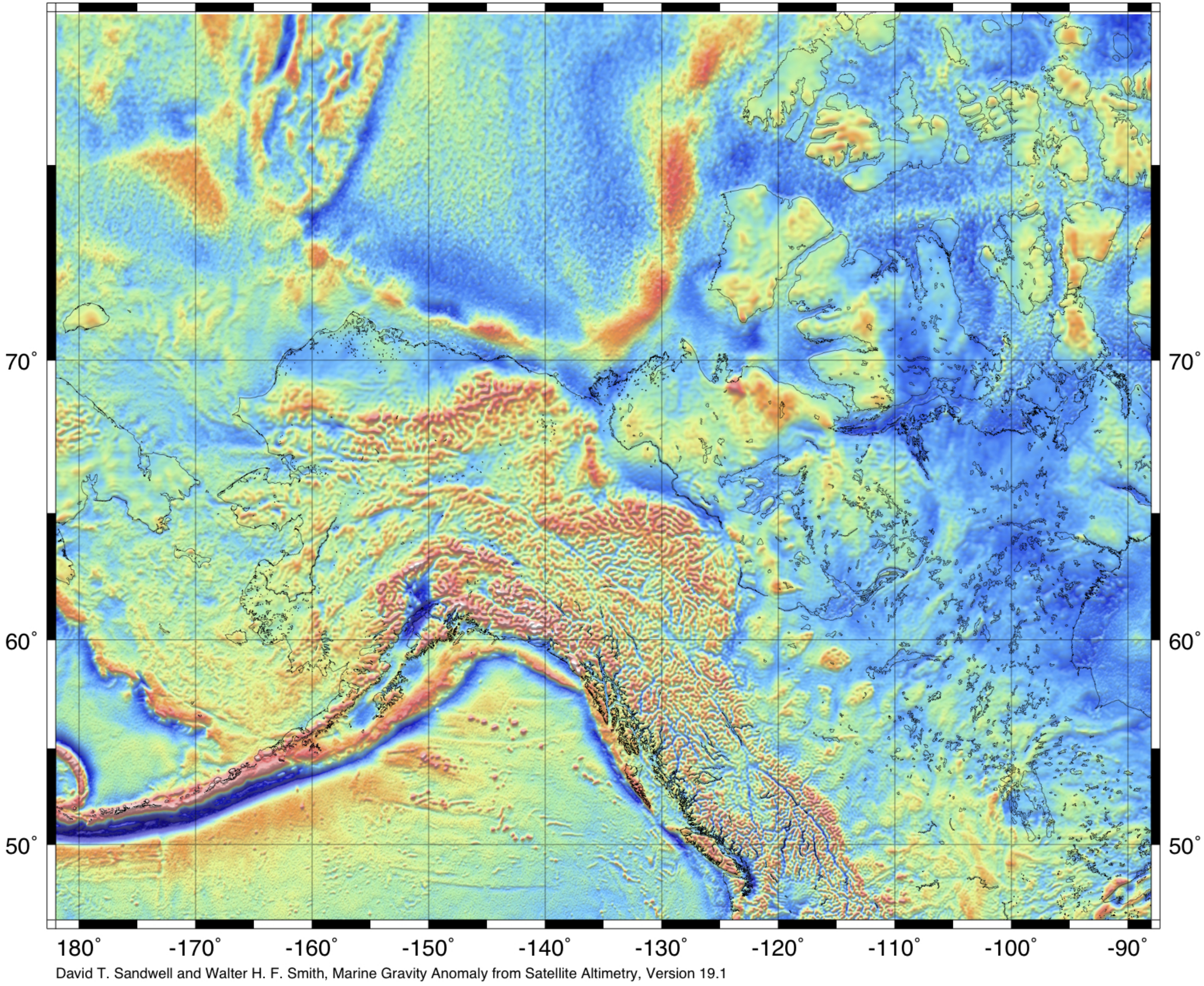
UCSD, Satellite Geodesy Pages: https://topex.ucsd.edu/marine_grav/mar_grav.html

Details: Southeast Asia-Pacific



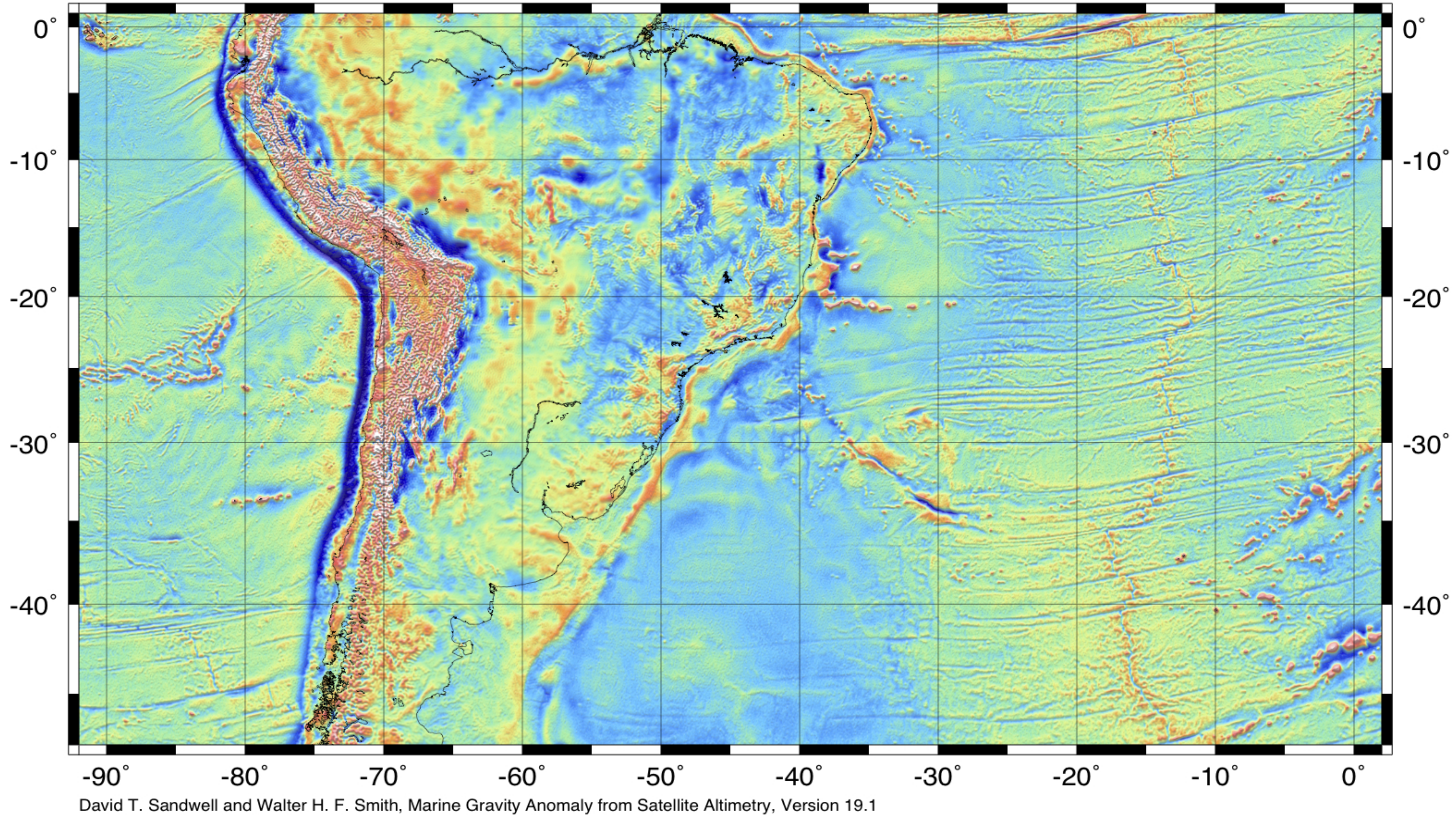
UCSD, Satellite Geodesy Pages: https://topex.ucsd.edu/marine_grav/mar_grav.html

Details: Arctic – Alaska, Aleutians



UCSD, Satellite Geodesy Pages: https://topex.ucsd.edu/marine_grav/mar_grav.html

Details: South America & Atlantic



UCSD, Satellite Geodesy Pages: https://topex.ucsd.edu/marine_grav/mar_grav.html