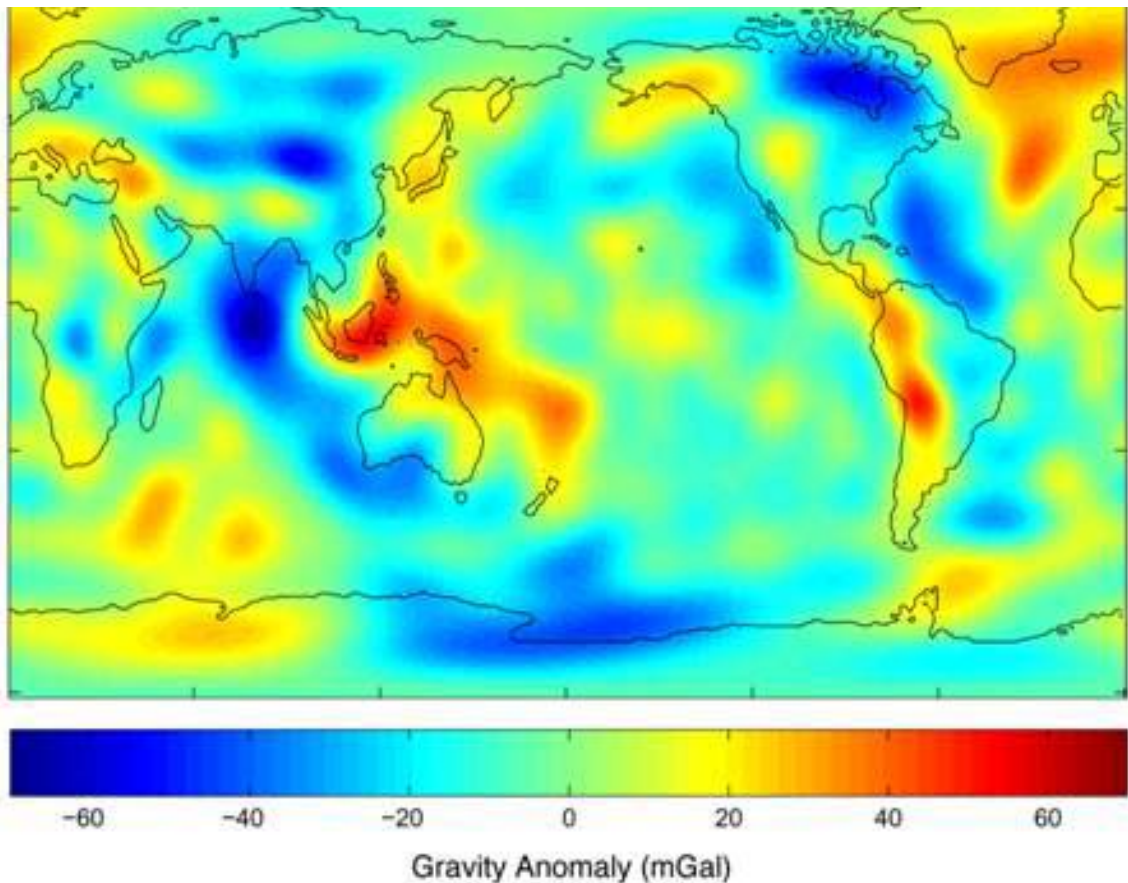


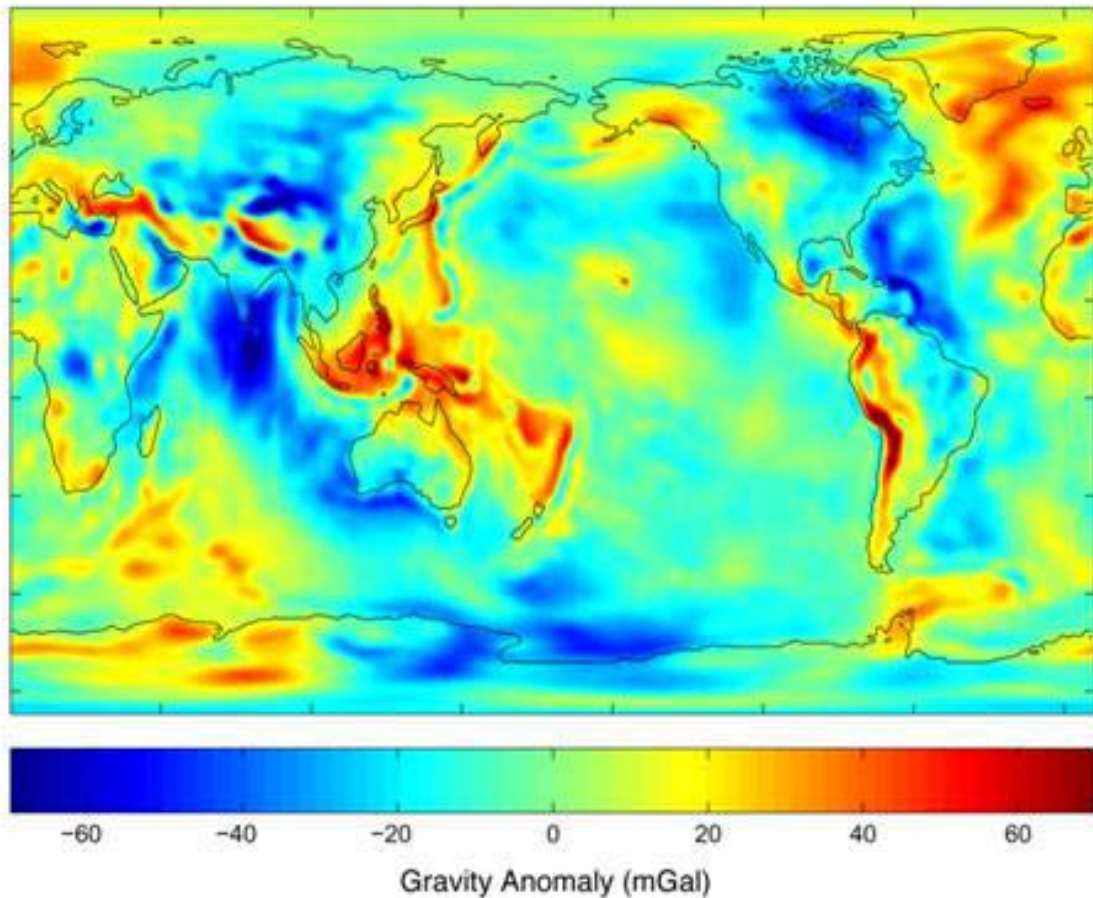
Earth's Gravity Field and Sea Level

The gravity field of the earth can vary in space. We already discussed one reason for this: the rotation of the earth and the effect of centrifugal force. Another reason is that the mass of the earth is not uniformly distributed: it is not a perfect oblate spheroid. This has been known for many years and painstaking gravity measurements on land (and from ships) have given us our first information about the variations in gravity. With the advent of artificial satellites (beginning with Sputnik), tracking of these low earth-orbiting satellites has shown that they do not move in perfect circles (or ellipses) while in orbit. From this information, we have been able to refine the knowledge about earth's gravity. One place to look at this is on the JPL website.

From the NASA website for the Jet Propulsion Laboratory (JPL):
<http://www.jpl.nasa.gov/>



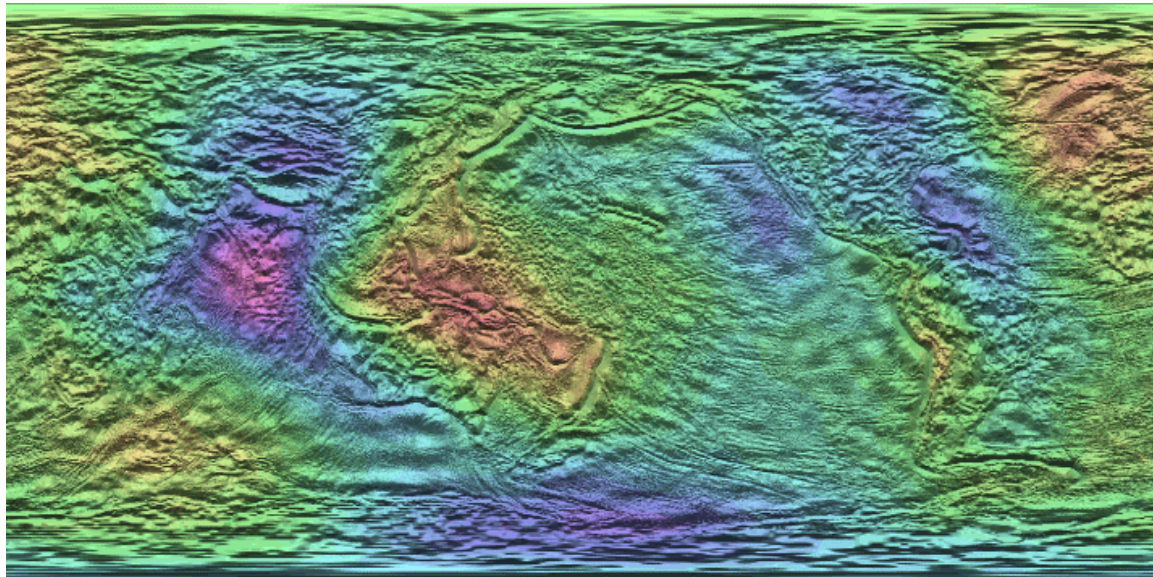
A milligal is a convenient unit for describing variations in gravity over the surface of the Earth. 1 milligal (or mGal) = 0.00001 m/s^2 , which can be compared to the total gravity on the Earth's surface of approximately 9.8 m/s^2 . Thus, a milligal is about 1 millionth of the standard acceleration on the Earth's surface. The above, determined from past tracking of earth-orbiting satellites shows that earth's gravity can vary up to $\pm 60 \text{ mGal}$. A recent satellite mission designed specifically to accurately measure the earth's gravity (GRACE) has greatly improved the above map (see below).



Much of the variability has yet to be explained, but one important element is the variation of the ocean depth (since seawater is less dense than rock or sediment). Also, different types of rock have different densities and this will cause spatial variations in gravity. Deep ocean basins will therefore have low gravity and mid-ocean ridges will have locally high values of gravity.

Because gravity varies, it will have a horizontal component over the oceans, which will be unbalanced unless the sea surface slopes to offset it. This can be computed for a given gravity model showing the spatial variations of mean sea level. This is given below by researchers at the Univ. Texas.

The CSR98 mean sea surface model determined by satellite altimeter data collected from GEOSAT, ERS-1, ERS-2 and TOPEX/POSEIDON missions



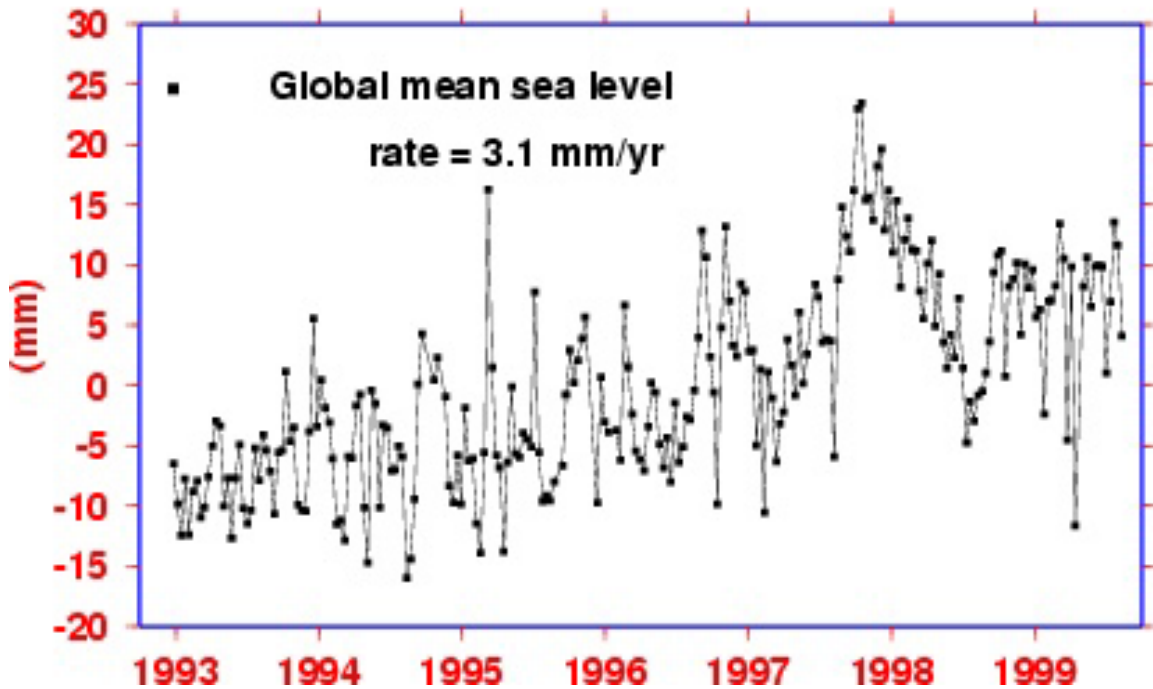
-100

+80

Mean Sea Surface Height (meter)

It is clear from this image, that sea 'level' actually changes in height with spatial variations of 100m over the oceans. This figure is similar to Fig. 3.22 in our text, but has the advantage that there is a scale, allowing us to see the magnitude of the spatial changes the 'surface geopotential' topography. As we will see in the discussion of sea level variations due to ocean flows, values of approximately 1 m are typical across many strong currents like the Gulf Stream. Since these are 100 times *smaller* than the observed variations, oceanographers usually look at *anomalies* from mean sea level which usually represent oceanic effects. Finally, we note that 'mean' sea level is changing! This can be due to changes in the solid earth (e.g glacial rebound) and changes in the amount and/or density of seawater. Again, from the U. Texas, we can see that mean sea level as seen from space over the recent seven years is increasing.

Global



Large year-to-year variations are not due to melting and re-freezing of glaciers, but are due to oceanographic processes (e.g. El Niño), which we will study in this class. Some effect of change in mean ocean temperature can also affect mean sea level since warmer seawater occupies a larger volume and will therefore increase sea level with no net addition of mass to the ocean. Of course, melting of multi-year sea ice will not have any effect since it was already floating to begin with!