Day 2 - September 1, 2011

Organizational things I forgot last time:

- Field Trip, EarthScope instrumentation, early Oct.

  Decide on a day that will work. Preliminary logistics.

- Prof. Geoff Blewitt will lecture, Sept 20 & 22, when I'm in Italy at the European Space Agency's FRINGE meeting on InSAR technologies and applications.

A First Introduction to Geodesy

The shape of the Earth, its rotation and gravitational field

The Geoid

Problem Set #1

Introduce and Discuss

Convert from XYZ coordinates to Latitude, Longitude and Height

Convert from XYZ displacements to NEU displacements

Review instructions

MATLAB - hows it going?

- issues & problems
- tinker time, lets get it going.

Reading

none today, but generally we will read a paper, and one member of the class will be pre-selected to lead discussion.

Introduction: The Three Pillars of Geodesy

- Earth Shape
- Earth Rotation
- Gravitational Field

In this class: We will focus on geometric aspects of Earth shape changes over time, and what they can tell us about for geophysical processes.

from James Smith "Introduction to Geodesy: The History and Concepts of Modern Geodesy"

PYTHAGORAS

Certainly by the time of Pythagoras (c. 580–500 B.C.) the earth was considered to be spherical—if for no other reason than that the sphere was thought by the philosophers of the time to be the perfect regular solid. As might be expected, not all authorities agreed, and even as late as the sixth century A.D., scorn was still being poured on the idea of a round earth and queries raised as to how such a shape could retain the waters of lakes and oceans.

If we had a table tennis ball, there would be no difficulty measuring its diameter with calipers. Enlarge this to a dome 1 km across, and, while the problem would be a little more difficult, there would still be several ways of measuring it. We might use techniques that were the reverse of setting out curves—for example, we could directly measure the tangent lengths or calculate offsets from a tangent and then do the necessary calculation.

But what happens when the dome has a radius of some 7000 km? Some totally different approach is required. Granted, in the light of methods available today, there would be no difficulty in using satellites, but what about 2000+ years ago, before the developments of the electronic age?

ARISTOTLE

First attempts at putting a dimension on the sphere are credited to Aristotle (c. 384–322 B.C.) who recorded a diameter of 400 000 *stades*. This figure could vary from 84 000 to 63 000 km, depending on our choice of conversion factor. But how he arrived at his value is unknown.

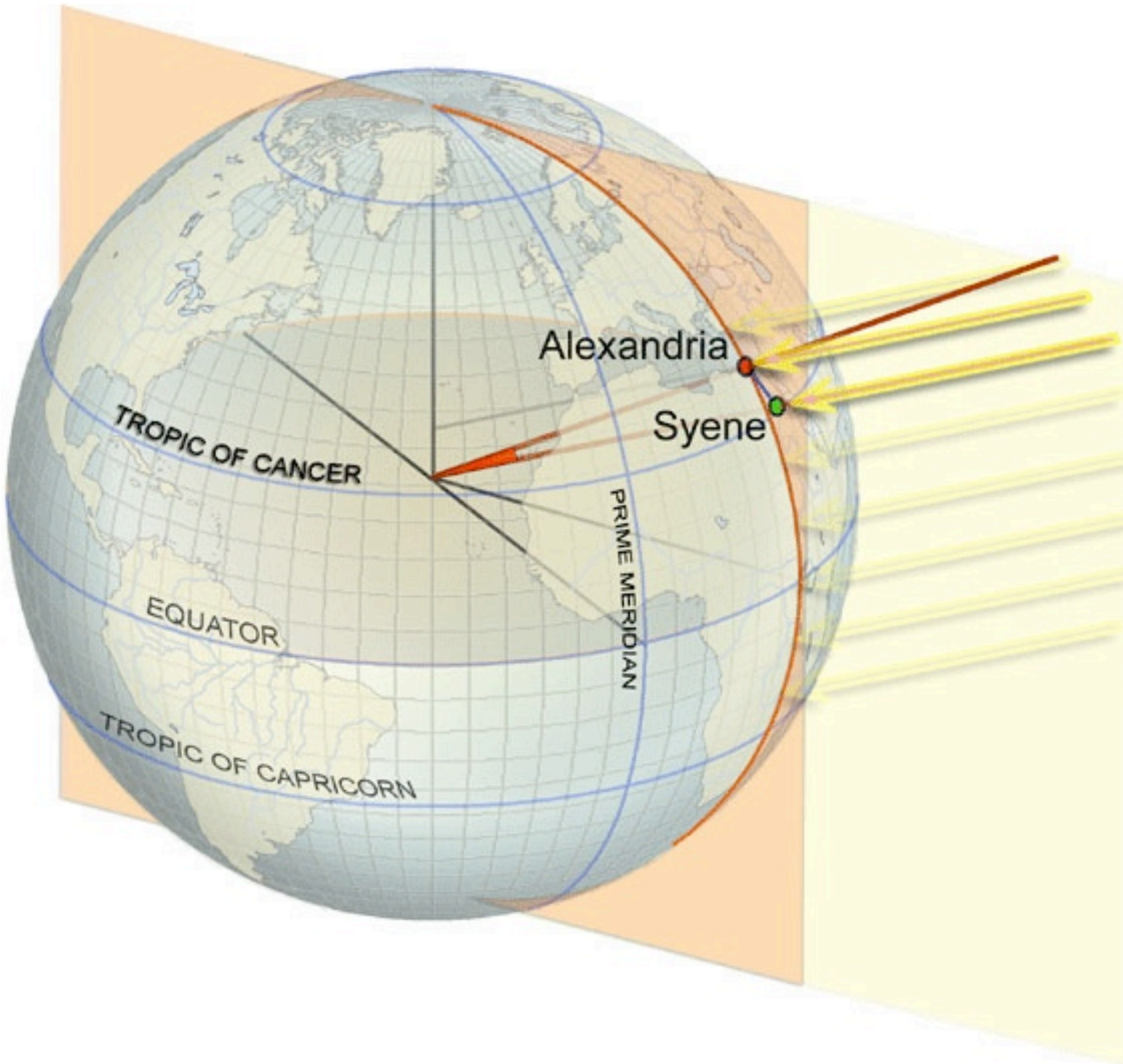
ARCHIMEDES

A century later, Archimedes quoted 300 000 stades (63 000 to 47 000 km). It might even be that each used a different length of stade and that both used the figures equivalent to 63 000 km—possibly from the same initial guess.

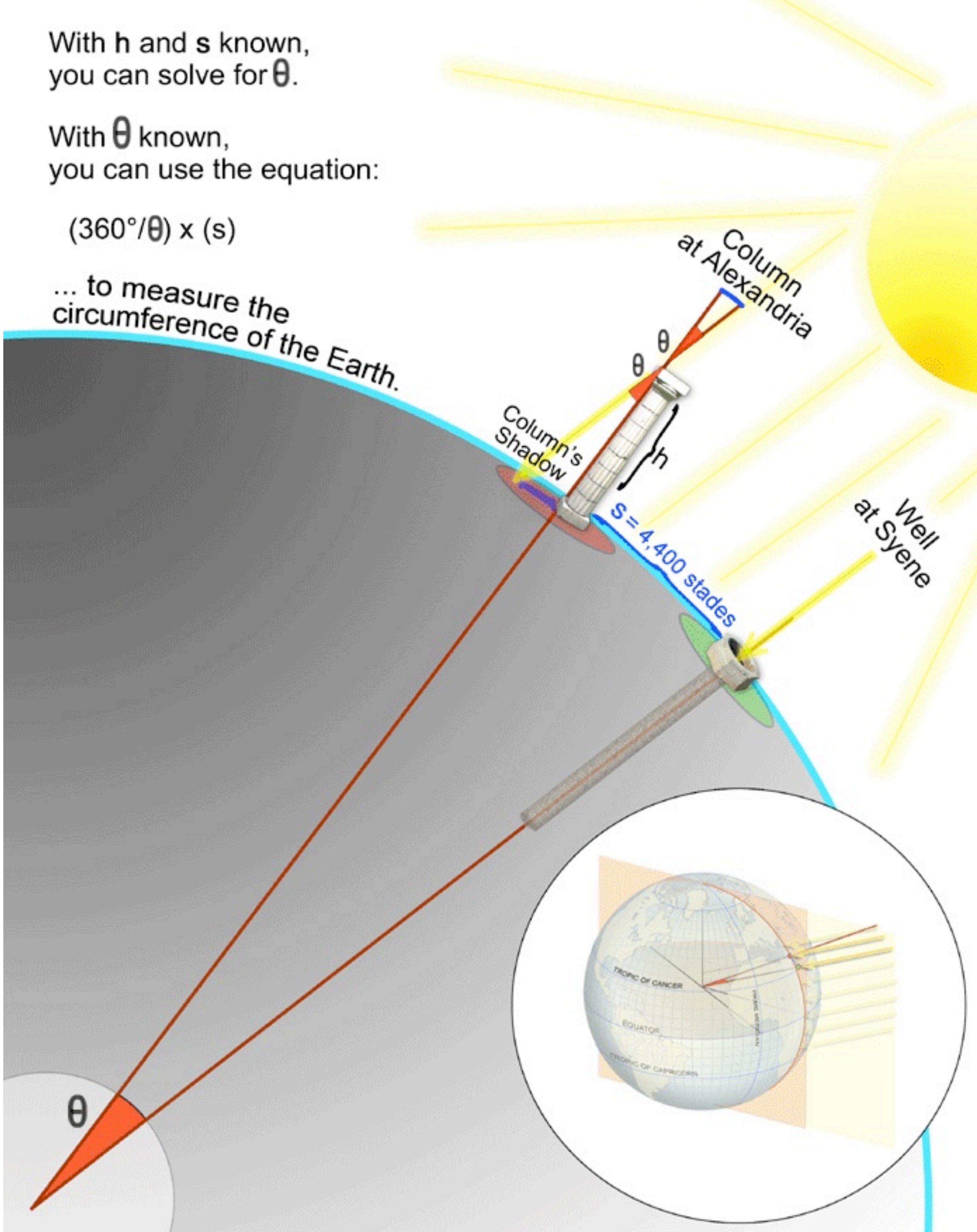
ERATOSTHENES

For an approach of any scientific significance we turn to Egypt, where the Greek philosopher Eratosthenes (276–195 B.C.) was librarian at the famous library in Alexandria. He adopted a principle, shown in figure 2, that is still acceptable today. If for the moment we assume the earth is a sphere, then its

Eratosthenes



from: http://oceanservice.noaa.gov/education/kits/geodesy

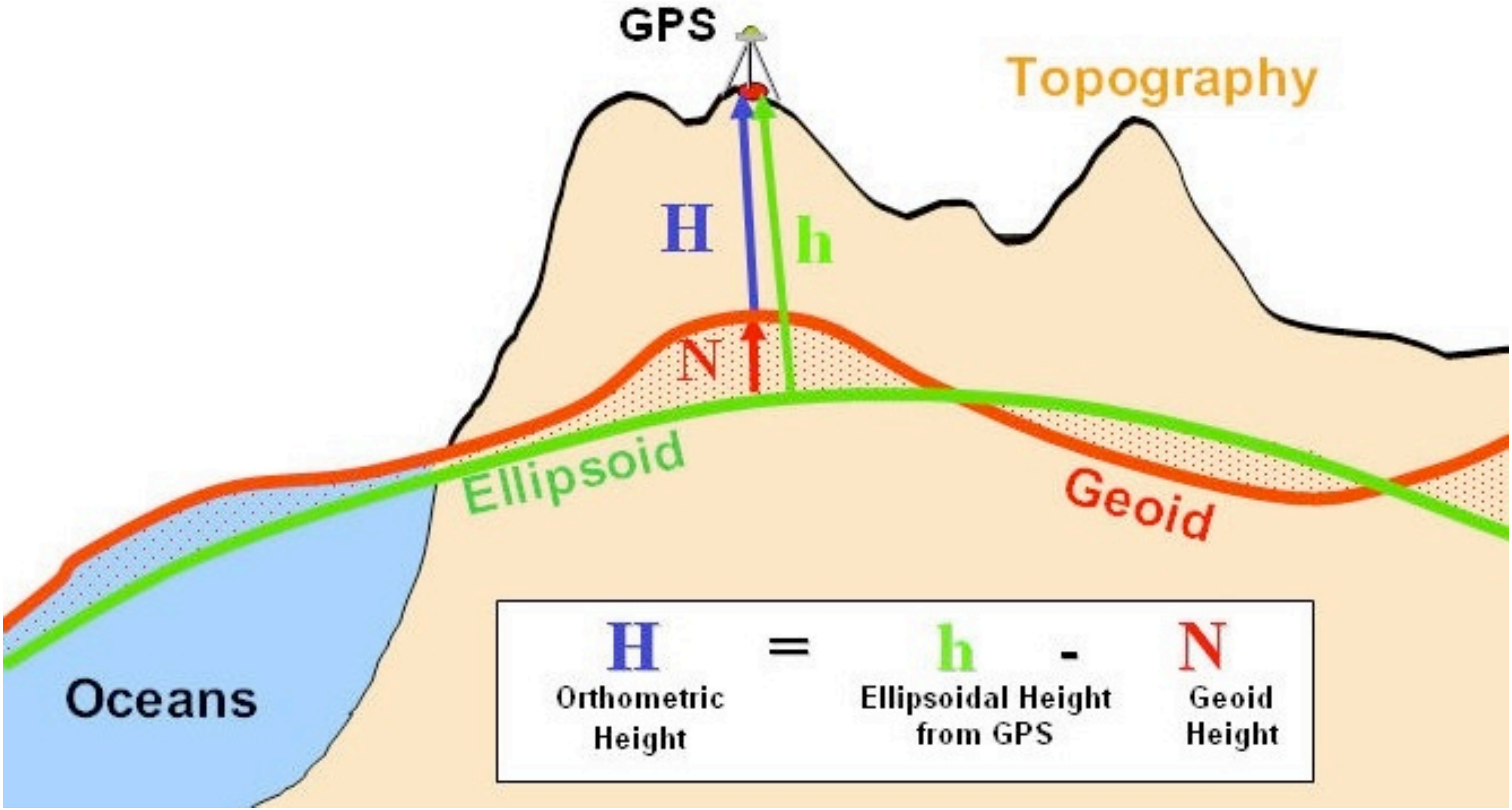


- He got a circumference of ~39,690 km, error of less than 2%.
- But nobody really knows how big his 'stadia' were

Datums

At the 1967 meeting of the IUGG held in Lucerne, Switzerland, the ellipsoid called GRS-67 (Geodetic Reference System 1967) in the listing was recommended for adoption. The new ellipsoid was not recommended to replace the International Ellipsoid (1924), but was advocated for use where a greater degree of accuracy is required. It became a part of the GRS-67 which was approved and adopted at the 1971 meeting of the IUGG held in Moscow. It is used in Australia for the Australian Geodetic Datum and in South America for the South American Datum 1969.

Reference ellipsoid name	Equatorial radius (m)	Polar radius (m)	Inverse flattening	Where used
Modified Everest (Malaya) Revised Kertau	6,377,304.063	6,356,103.038993	300.801699969	
Timbalai	6,377,298.56	6,356,097.55	300.801639166	
Everest Spheroid	6,377,301.243	6,356,100.228	300.801694993	
Maupertuis (1738)	6,397,300	6,363,806.283	191	France
Everest (1830)	6,377,276.345	6,356,075.413	300.801697979	India
Airy (1830)	6,377,563.396	6,356,256.909	299.3249646	Britain
Bessel (1841)	6,377,397.155	6,356,078.963	299.1528128	Europe, Japan
Clarke (1866)	6,378,206.4	6,356,583.8	294.9786982	North America
Clarke (1878)	6,378,190	6,356,456	293.4659980	North America
Clarke (1880)	6,378,249.145	6,356,514.870	293.465	France, Africa
Helmert (1906)	6,378,200	6,356,818.17	298.3	
Hayford (1910)	6,378,388	6,356,911.946	297	USA
International (1924)	6,378,388	6,356,911.946	297	Europe
NAD 27 (1927)	6,378,206.4	6,356,583.800	294.978698208	North America
Krassovsky (1940)	6,378,245	6,356,863.019	298.3	Russia
WGS66 (1966)	6,378,145	6,356,759.769	298.25	USA/DoD
Australian National (1966)	6,378,160	6,356,774.719	298.25	Australia
New International (1967)	6,378,157.5	6,356,772.2	298.24961539	
GRS-67 (1967)	6,378,160	6,356,774.516	298.247167427	
South American (1969)	6,378,160	6,356,774.719	298.25	South America
WGS-72 (1972)	6,378,135	6,356,750.52	298.26	USA/DoD
GRS-80 (1979)	6,378,137	6,356,752.3141	298.257222101	
NAD 83	6,378,137	6,356,752.3	298.257024899	North America
WGS-84 (1984)	6,378,137	6,356,752.3142	298.257223563	Global GPS
IERS (1989)	6,378,136	6,356,751.302	298.257	
IERS (2003)[2]	6,378,136.6	6,356,751.9	298.25642	Global ITRS



- What is height?
- Which direction is up?

The Geoid

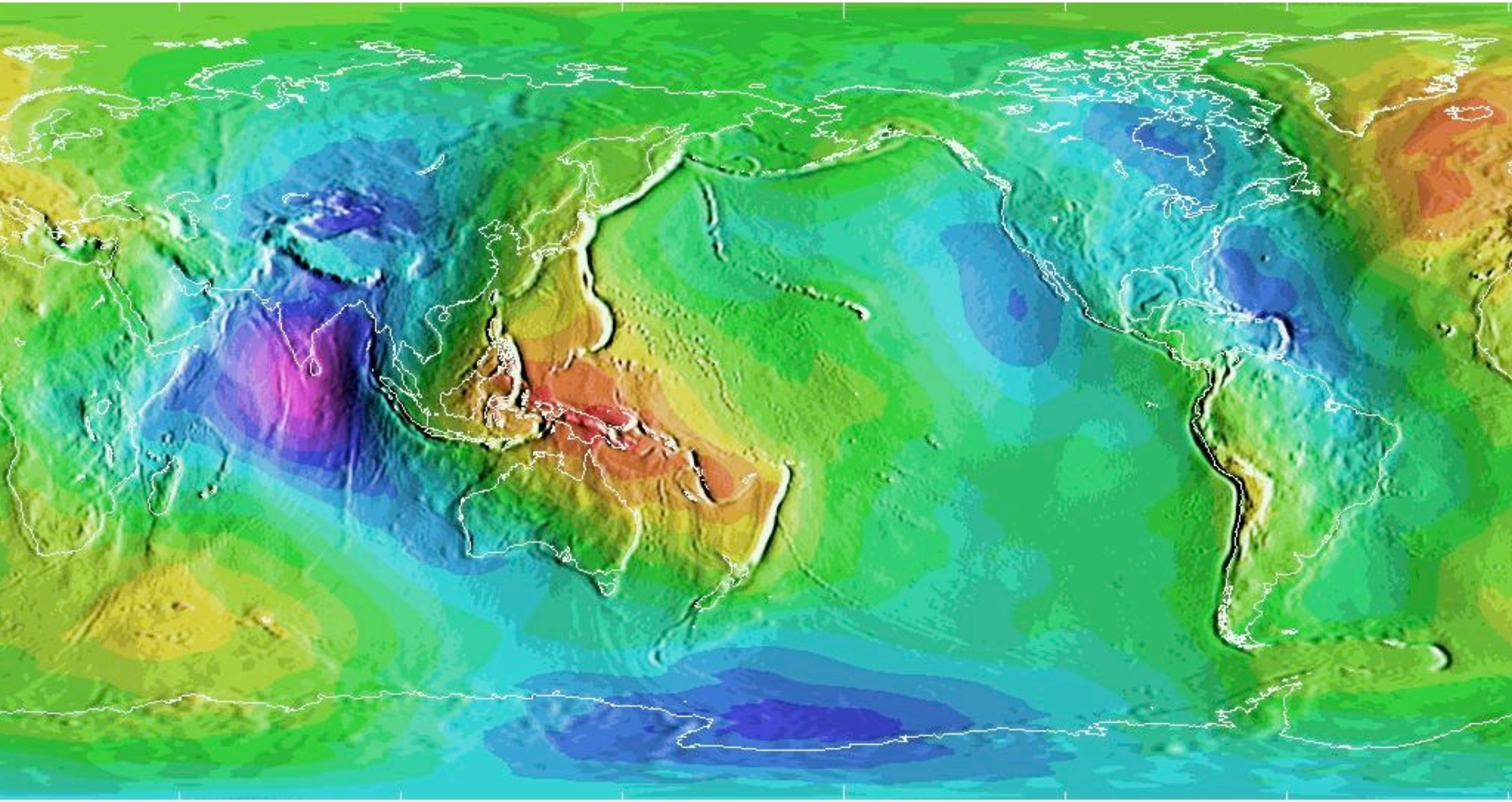
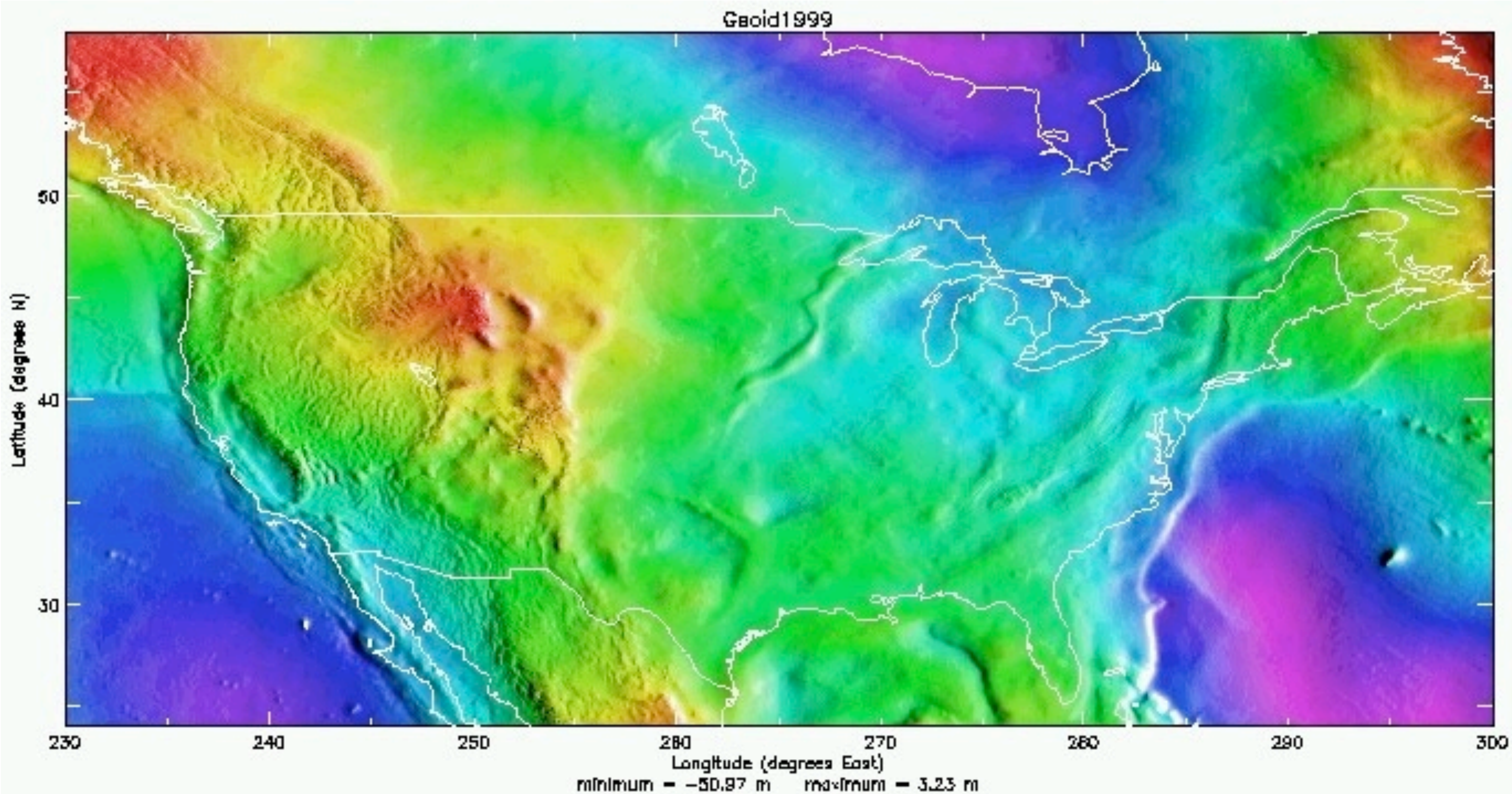


Image Name : ww15mgh; Boundaries : Lat -90N to 90N; Lon 0E to 360E;
Color Scale, Upper (Red) : 85.4 meters and higher; Color Scale, Lower (Magenta) :-107.0 meters and lower
Data Max value : 85.4 meters Data Min value :-107.0 meters Illuminated from the : East

figure taken from http://principles.ou.edu/earth_figure_gravity/geoid/index.html



GEOID99 *is a refined model of the geoid in the United States, which supersedes the previous models GEOID90, GEOID93, and GEOID96. For the conterminous United States (CONUS), GEOID99 heights range from a low of -50.97 meters (magenta) in the Atlantic Ocean to a high of 3.23 meters (red) in the Labrador Strait. However, these geoid heights are only reliable within CONUS due to the limited extents of the data used to compute it. GEOID99 models are also available for Alaska, Hawaii, and Puerto Rico & the U.S. Virgin Islands.*

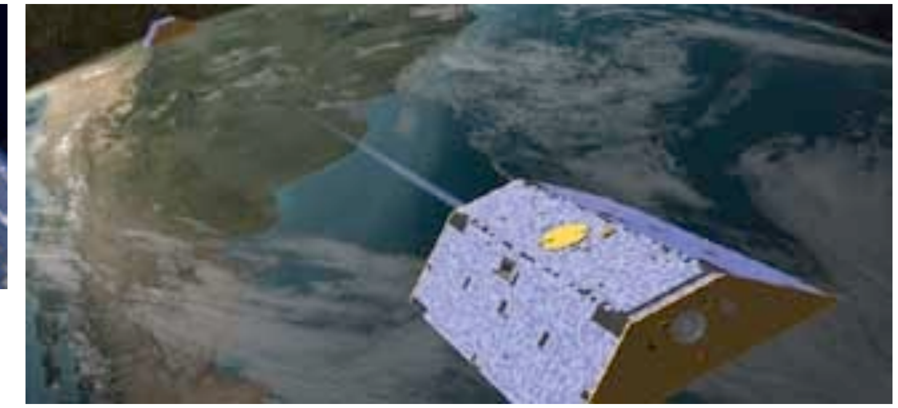
See also: Smith, D. A., and D. R. Roman (2001), GEOID99 and G99SSS: 1-arc-minute geoid models for the United States, *Journal of Geodesy*, *75*, 469-490.

Piazza San Marcos,
Venice Italy


GONDOLE

The Point

- Global sea level rise ongoing at the level of ~1 mm/yr. Contributions from melting of ice and steric (temperature and salinity) of oceans.
- Regional variations owing to different mechanisms behind sea level increase
- Coastal subsidence exacerbates effects of sea level rise
- Earth shape changes at local, global levels can contribute to site specific effects.
- Venice going down at ~1 mm/yr wrt Earth Center of Mass.



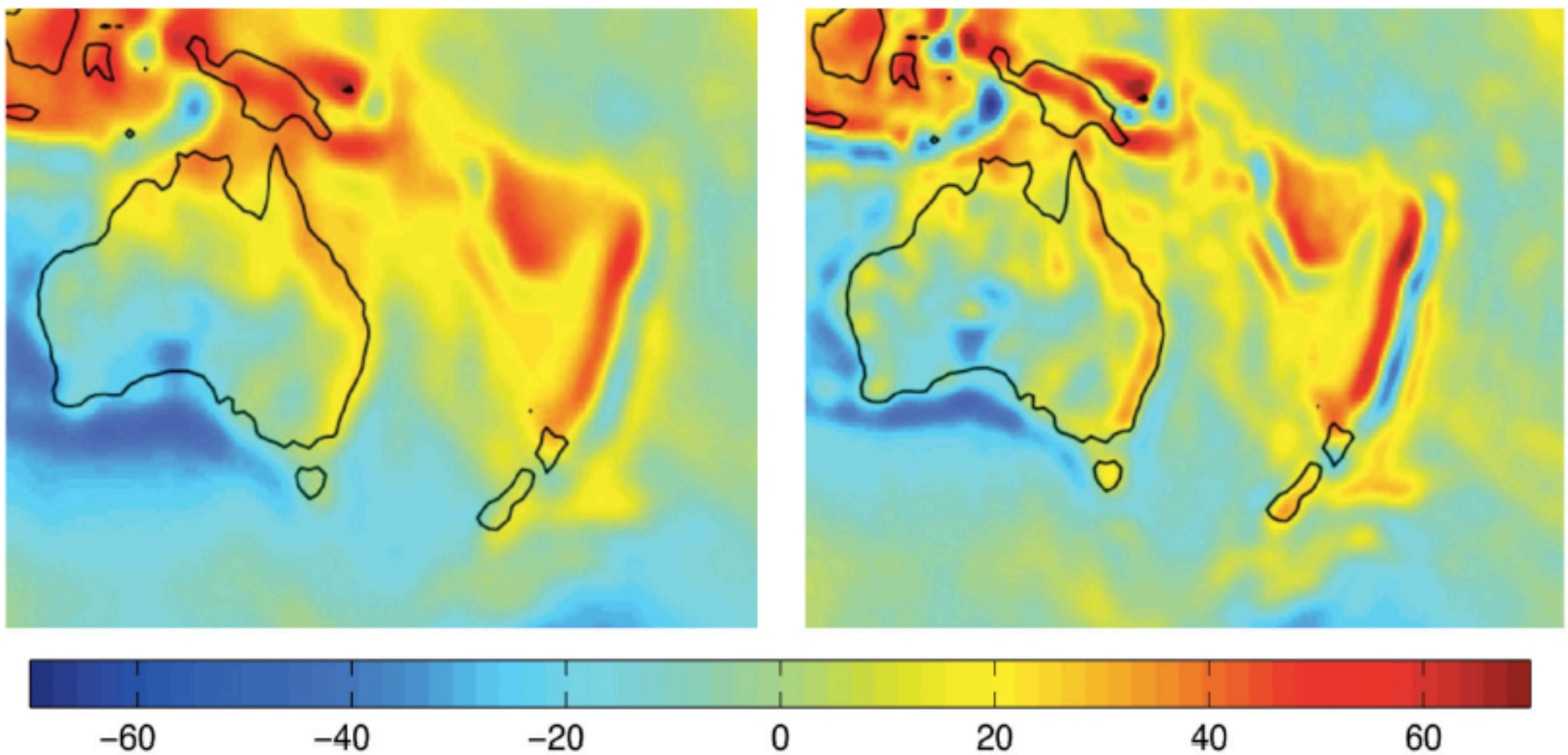


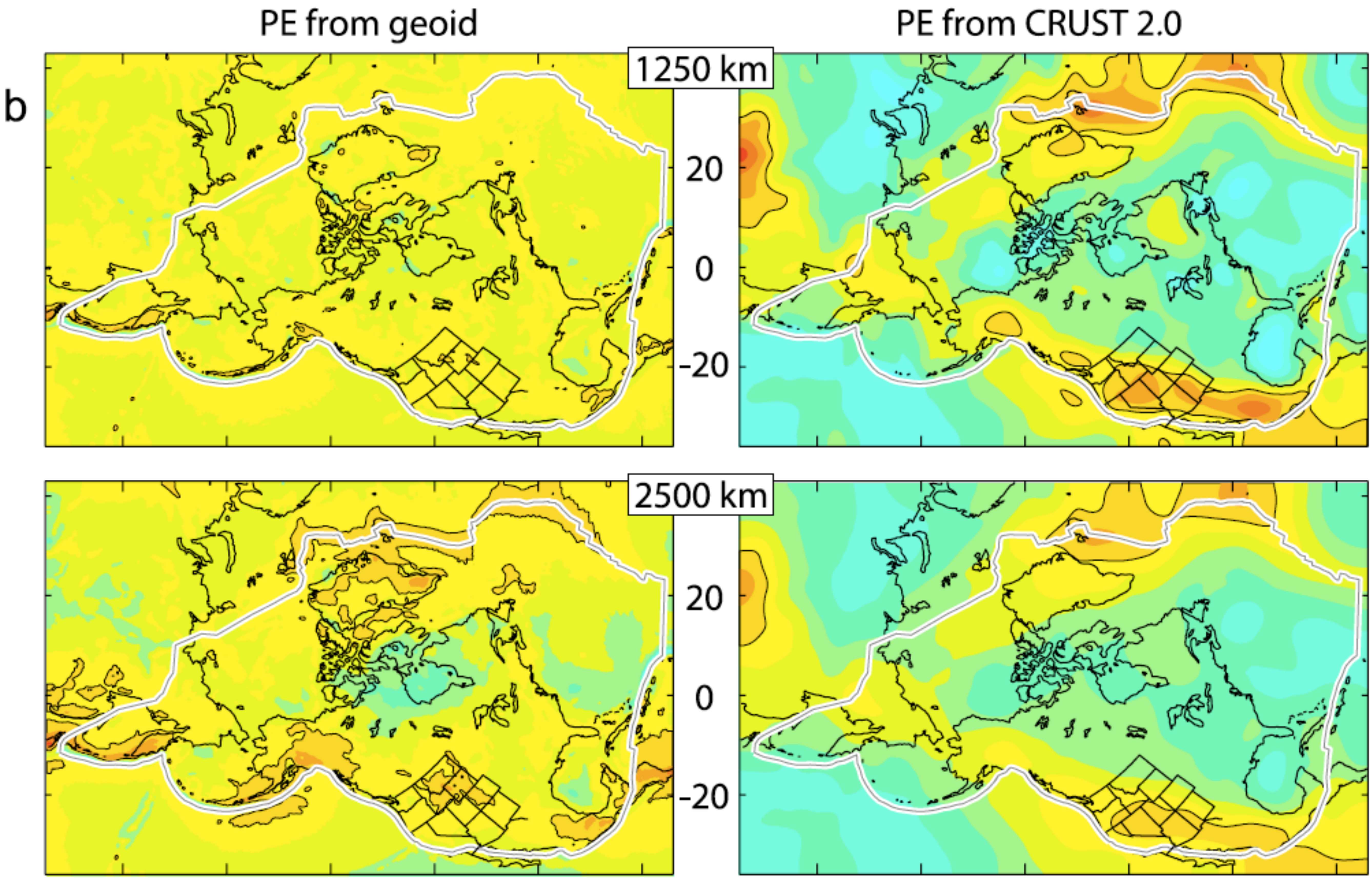
Figure 3. Improvement in resolution in gravity anomalies computed from GGM02S (right) compared to GGM01S (left) in the Tonga-Kermadec region. With the increased accuracy of the GGM02S model, less smoothing is required to remove artifacts and more detail is revealed. Units are mgal.

How Big Are These Gravity Variations?

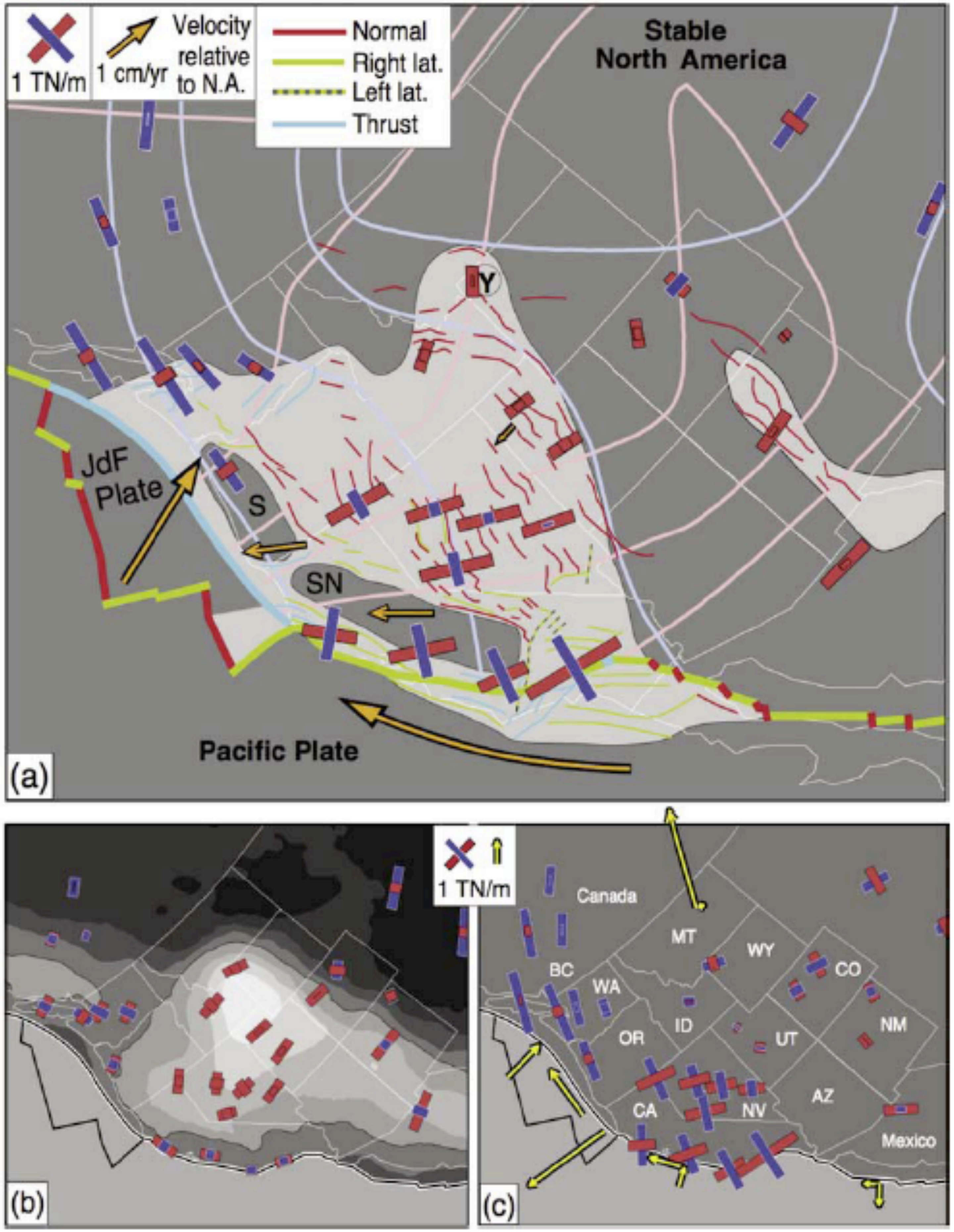
- In previous figure gravity varied by ~100 mgals = 0.1 gals = 0.1 cm/s^2 = .001 m/s^2
- Acceleration owing to Earth's surface gravity field is near 9.8 m/s^2
- Variation in gravity is around 1 part in 10^4 (.01%)

Geodynamic Significance of Geoid

- Equation from Coblentz et al.
- Equation from Turcotte & Schubert
- Can estimate variations in gravitational potential energy in the lithosphere
- Which can be used to estimate state of stress in the lithosphere owing to gravity forces.
- Which can be combined with plate boundary stress estimates to estimate stress on edges of the plates.



PE from geoid
PE from CRUST 2.0
b
1250 km
20
0
-20
2500 km
20
0
-20



Humphreys and Coblentz, 2007