ESS345 – assignment 2:
volume of oceans, and sea-level variation

In this assignment you will calculate the how much water is in the ocean, and by how much sea level will rise if the existing large continental ice sheets on Greenland and in Antarctica would melt.

0. Key concepts of this assignment

geologic concepts: map projections, coastal inundation
mathematical concept: trigonometric functions
programming concepts: loops, data visualization

1. Digital elevation data

Matlab comes with a 1×1-degrees digital elevation file; use `load topo.mat` and follow up with `figure; pcolor(topo); axis image; shading flat` to view the data. I suggest you check what the `axis` and `shading` commands do. You may also play with the `surf` command, and change `colormap`, `view` and lighting.

2. individual task

Using the crude topography dataset from Matlab you can estimate the volume of water in Earth's oceans, and how sea level would change in response to the melting of ice sheets.

student A: size of 1-by-1 degree tiles

Assuming a spherical earth (with 6,371 km radius) you need to calculate the area of each 1-by-1 degree cell. Note that this area becomes smaller and smaller as one moves from equator to pole. This is because one degree in latitude (*e.g.* from 37°N to 38°N does not change in size from equator to pole, but the longitude degrees become smaller and smaller. You need to use trigonometric relations to determine these lengths.

student B: volume of oceans

Depth to the ocean floor is indicated by negative values in the variable `topo`. You need to select only those cells (you may use the `find` command) and sum up their volumes. For your part assume that 1 degree in latitude is 100 km long, while 1 degree in longitude is 60 km wide.

student C: location of ice sheets

We will assume that without ice the surfaces of both Greenland and Antarctica would be at sea level. While you can safely assume that all elevation values below 0 mark an oceanic tile, you need to select those tiles above zero that actually are part of Greenland and Antarctica. I suggest you use the `ginput` and `inpolygon` commands for Greenland. Show that you have selected the correct tiles.

3. continuing the assignment as a group

You now need to calcuate the amount of meltwater and distribute if over the existing oceanic area, plus adjacent coastal cells.

First you need to re-calculate the volume of ocean water using the correct areas of the map tiles.

Then you need to determine the volume of these landmasses that is above sea level; this is the total volume of ice that would melt. Note that 1 km^3 will not produce the exact same volume of water.

How can you determine which coastal cells will be covered by seawater?

Show the change in coastline on the world map.

Think about the sections of the report. Which information should go into each section? I suggest you brainstorm about this together, and then decide who writes which section.

In your report, please also think about the accuracy of your calculations. How good are your assumptions, and where are potential error sources? Are there additional factors that contribute to sea-level variations? These thoughts you should include in the discussion.

4. looking back in time

During the last ice age, sea level was about 130 m lower than today (which allowed for example for a land bridge between Alaska and Russia). What was the volume of ice at that time compared to today?

How would you add this information to your report?

Appendix: More on digital elevation models and map projections

You may recognize that the map you have produced above is a very crude projection; each degree tile is a square. The Matlab elevation file is sufficient for whole Earth projections; however each grid cell is over 100 km wide at the equator and thus not suited for more detailed maps. NOAA has published ETOPO1, which has elevation data at the 1-minute scale (about 1.5 km cell size) and even the 1 km GLOBE dataset (see NOAA, 2014).

A map is essentially a projection of some or all of Earth's curved surface onto a plane. For this assignment we assume a spherical Earth, though we know that an oblate ellipsoid that is 20km shorter at the pole is a better approximation of mean sea level, and an even more precise one is the "geoid" that deviates an additional ± 80 m from that ellipsoid.

A map projects latitude and longitude that describe a position on the globe onto positions on a simpler projection surface. This surface is either a plane (azimuthal projection) or a cylinder or a cone; the latter two can easily be unwrapped to become a plane. Formulas to realize many map projections are detailed in Snyder and Voxland (1989), and those for select projections can be found online at Weisstein (2014). Dana (2000) shows visual examples of map projections, while Pawlowicz (2011) has created a Matlab toolbox with various projections.

Because any map projection relates a point on the sphere to a point on a plane, any projection distorts surface relations like distances, areas, shapes, and angles. As a consequence, we have to choose the projection according to our objective. Cartographers have come up with many different projections that fit different purposes. Some projections may preserve areas, or shape, or distance from a central point, or angles. For example, many of you will be familiar with the Schmidt net used in structural geology (it preserves area) or the Wulf net used in crystallography (it preserves angles).

To try out the various types of map projections, I suggest you download the m_map package and try it out. You may run the `mapstuff2.m` script to view a few projections with Toronto at the centre.

References

Dana, P. H., 2000. Map projection overview. The Geographer's Craft Project, Department of Geography, The University of Colorado at Boulder. Accessed 07 Feb 2014 at http://www.colorado.edu/ geography/gcraft/notes/mapproj/mapproj f.html

NOAA, 2014. ETOPO1 global relief model. Accessed 08 Feb 2014 at http://www.ngdc.noaa.gov/mgg/global/global.html

Pawlowicz ,.R., 2011: M_Map: a mapping package for Matlab. Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia, accessed 08 Feb 2014 at http://www2.ocgy.ubc.ca/∼rich/map.html

Snyder, J. P., and P. M. Voxland, 1989. An album of map projections. U.S. Geological Survey, Denver, Colorado, 249 pg. [U of T call number GA110 .S575 1989, Map Collection]

Weisstein, E. W., 2014. Map projection. MathWorld - A Wolfram Web Resource. Accessed 07 Feb 2014 at http://mathworld.wolfram.com/MapProjection.html