

Title:	Using GRACE to evaluate change in Greenland's ice sheet
	Part I: Download, import and map GRACE data
	Part II: View and animate seasonal ice sheet mass changes
	Part III: Calculate and visualize annual ice sheet mass changes
	Part IV: Calculate annual mass loss rate
Product Type:	Curriculum
Developer:	Helen Cox (Professor, Geography, California State University, Northridge): helen.m.cox@csun.edu Laura Yetter (Research Asst., Institute for Sustainability, California State University, Northridge)
Target audience:	Undergraduate/Graduate
Format:	Tutorial (pdf document)
Software requirements* :	ArcMap 9 or higher (ArcGIS Desktop) (Parts I, II, III, IV), ArcGIS Spatial Analyst (Parts III, IV)
Data:	All data required are obtained within the exercise.
Estimated time to complete:	All parts: 5.5 hrs
	Part I: 2 hrs.
	Part II: 0.5 hrs.
	Part III: 1.5 hrs. - 2 hrs.
	Part IV: 1 hr.
Alternative Implementations:	<ul style="list-style-type: none"> • Part I provides a standalone exercise producing a map of ice sheet mass • Parts I and II together provide a standalone exercise producing an animation of seasonal change in ice sheet volume • Parts I, II and III together provide a standalone exercise to produce animations of seasonal and annual ice sheet volume changes • Completing all parts (I through IV) include calculations of the total decadal mass change and corresponding sea level rise
Learning objectives:	Part I: <ul style="list-style-type: none"> • Understand the GRACE satellites and how they measure gravity • Understand the application of GRACE to measure ice sheet volume • Download, import and map GRACE data
	Part II: <ul style="list-style-type: none"> • View GRACE data in ArcGIS • Create an animation of seasonal ice sheet changes
	Part III: <ul style="list-style-type: none"> • Create an animation of annual ice sheet volume • Generate images to show annual changes in ice sheet mass • Calculate change in ice sheet mass over past decade
	Part IV: <ul style="list-style-type: none"> • Compute annual and decadal ice sheet mass change • Compute sea level rise

*Tutorials may work with earlier versions of software but have not been tested on them

Using GRACE to evaluate change in Greenland's ice sheet

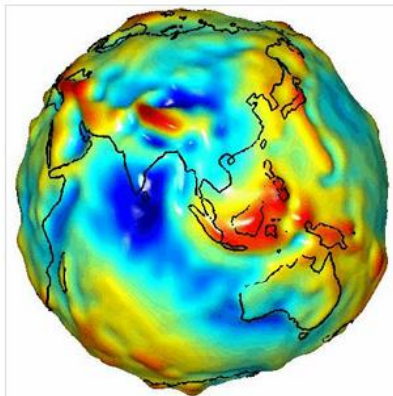
Part I: Download, import and map GRACE data

Objectives:

- Understand the GRACE satellites and how they measure gravity
- Understand the application of GRACE to measure ice sheet volume
- Download, import and map GRACE data



Gravity Recovery and Climate Experiment (GRACE) twin satellites include innovative technology that collects unprecedented information about the earth from space. GRACE measures the gravity field of the earth by flying two satellites approximately 220 kilometers (137 miles) apart (that would be for example from Los Angeles to San Diego) on the same path with one ahead of the other. The gravitational field of the earth which holds the satellites in orbit will pull the satellites differentially as their orbits change in response to variations in gravity over different regions of the earth. Mountains will cause increases in the pull of gravity and depressions such as an abyss will cause a weaker pull of gravity.



Warts and all: The Earth as seen by the GRACE satellites. The red spots represent places where the Earth's gravity is unusually strong. The blue ones are where it's weak.

Credit: NASA/University of Texas Center for Space Research

These variations change the speed and the distance between the two satellites, and are measured using a microwave instrument that shoots a beam between the two satellites which can sense changes as small as 10 microns (less than the thickness of a human hair) in the distance between the satellites. These measurements are used to create an Earth gravity map which can change within as short a time as a month as the distribution of weight on earth changes according to movement of water and geological processes. Earth's gravity map therefore provide information on water reservoir locations, post glacial rebound, tectonic movement, melting ice, precipitation distribution and sea level fluctuation efficiently on a global scale. GRACE can help farmers allocate water use, prepare regions for floods, assess the rate of glacial melt, monitor the global climate, and more.

For more info, see http://grace.jpl.nasa.gov/files/GRACE_Press_Kit.pdf

or http://grace.jpl.nasa.gov/files/GRACE_Fact_Sheet.pdf

(Text adapted from <http://www.cosmosmagazine.com/features/online/1678/gravity-ball>)

GRACE is a joint operation by the US NASA, German DLR, and European ESA space agencies. The two satellites, launched on March 17, 2002, are each 3 meters long and orbit the earth 16 times a day. They are in a polar orbit 500 km (311 miles) above the earth. In this set of exercises we will use GRACE data

to explore how the ice sheet mass changes throughout the year in response to seasonal variations and then evaluate the change in mass of Greenland's ice sheet over the past decade.

Data:

We will work with the level 2 monthly mass grids, which are observed changes in the mass over land. Mass changes are mostly due to changes in water storage in the atmosphere and in the cryosphere. (<http://grace.jpl.nasa.gov/data/gracemonthlymassgridsoverview/>).

An overview of these data can be found at: <http://grace.jpl.nasa.gov/data/gracemonthlymassgridsland/>.

It is important to obtain the correct version of the data. See the following release from August, 2012:

"The GRACE project has begun the release of version 5.0 for the Level 2 data. Tellus will begin processing the release 5.0 data into the products that are currently available for release 4.0. To prepare for the new release 5.0 data a new folder "RL04" has been added to the mass grid directories. When release 5.0 data become available it will be under the "RL05" folder. Since it will take a while for all the L2 data to be processed into release 5.0, releases 4.0 and 5.0 will be available simultaneously. Once the processing of release 5.0 is complete, release 4.0 data will be moved into the retired directory (<ftp://podaac.jpl.nasa.gov/allData/tellus/retired>)."

We'll work with RL05 data. First we will examine how the ice sheet mass changes throughout a year.

We will first investigate how the ice sheet mass changes throughout a year using 2009 as our sample.

1. Go to ftp://podaac-ftp.jpl.nasa.gov/allData/tellus/L3/land_mass/RL05/geotiff/

We'll use the Geotiff format because it is easiest to import in ArcGIS or Imagine and contains geographic coordinate information.

Download all the months for 2009 and save in a designated folder.

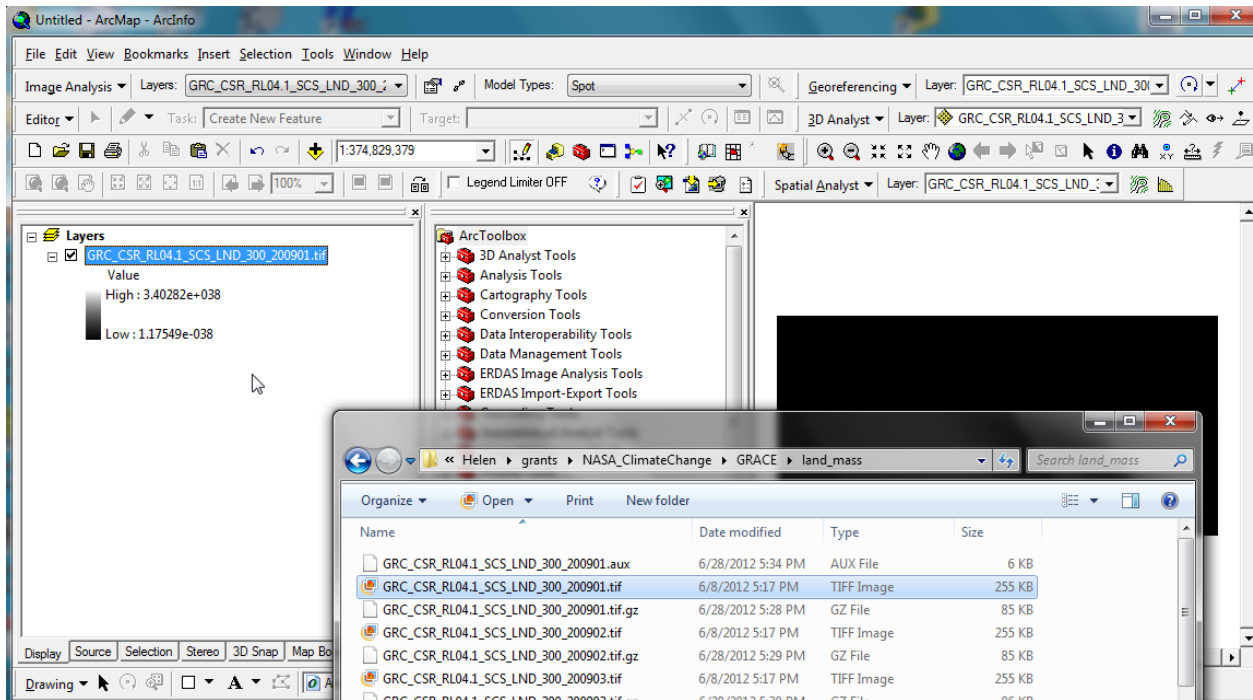
Naming convention is:

GRC_CSR_RL04.1_SCS_LND_300_yyyymm (GRC_CSR_RL04.1_SCS_LND_300_200907 for July)

(GRACE_Center for Space Research_Version_SCS_Land_Smoothing radius km_YYYYMM)

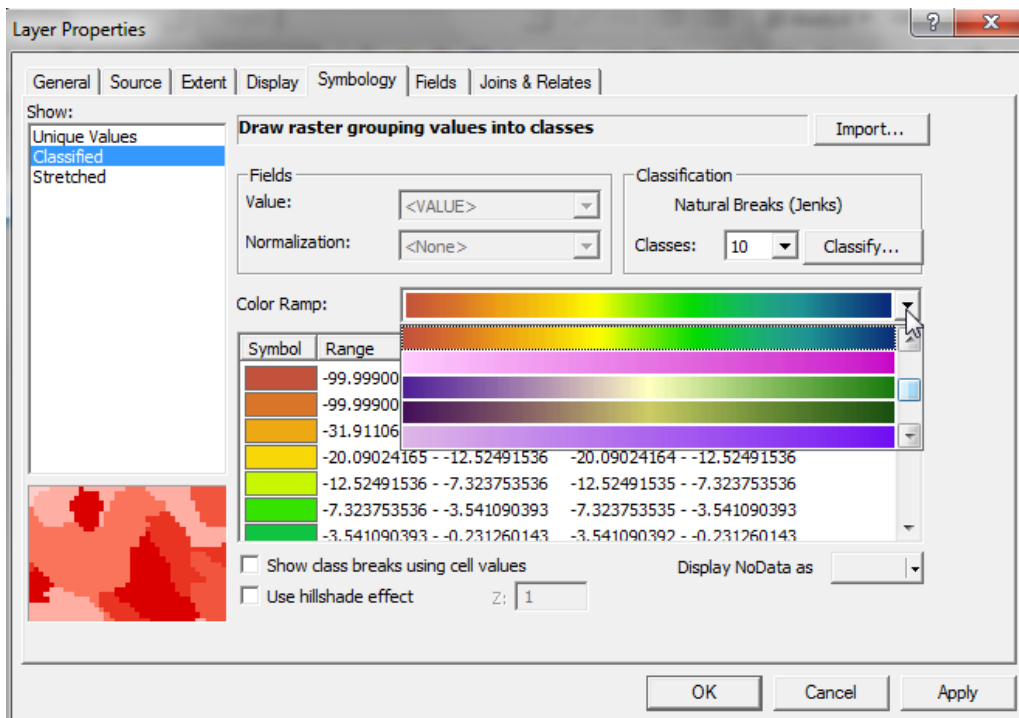
2. Unzip the files using WinZip, 7-Zip or some other unzipping software. (With 7-Zip you can unzip them all at once by highlighting all the files first.)

3. Display an image in ArcGIS by opening ArcGIS with an empty map and dragging one of the .tifs over to the left panel.

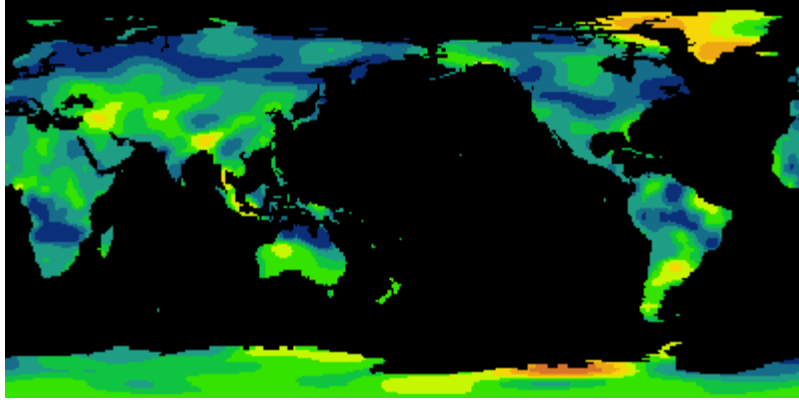


You will see that the coordinates are long, lat (degrees).

4. Choose a better scale for the symbology, eg.:

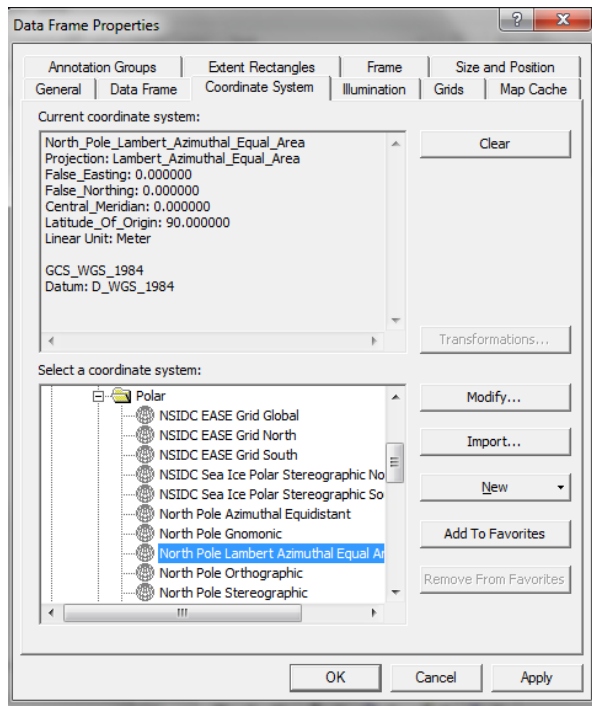


Then change the ocean to black.

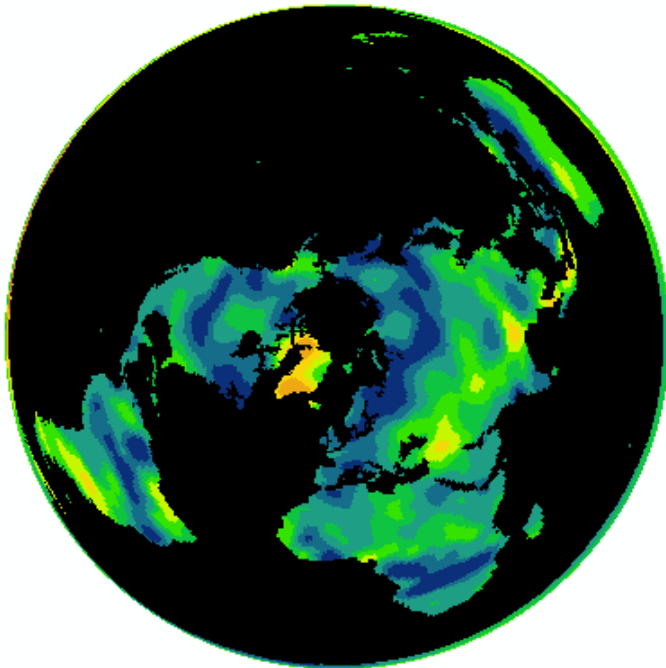


(To preserve the symbology so that it is the same the next time you open the image in ArcGIS, right click on the image in the Table of Contents then Save as Layer File->Check the file name (edit out the .tif and just use .lyr as the extension) and the file location and click Save. In future, open the lyr file in ArcGIS and it will automatically be linked to the .tif data.)

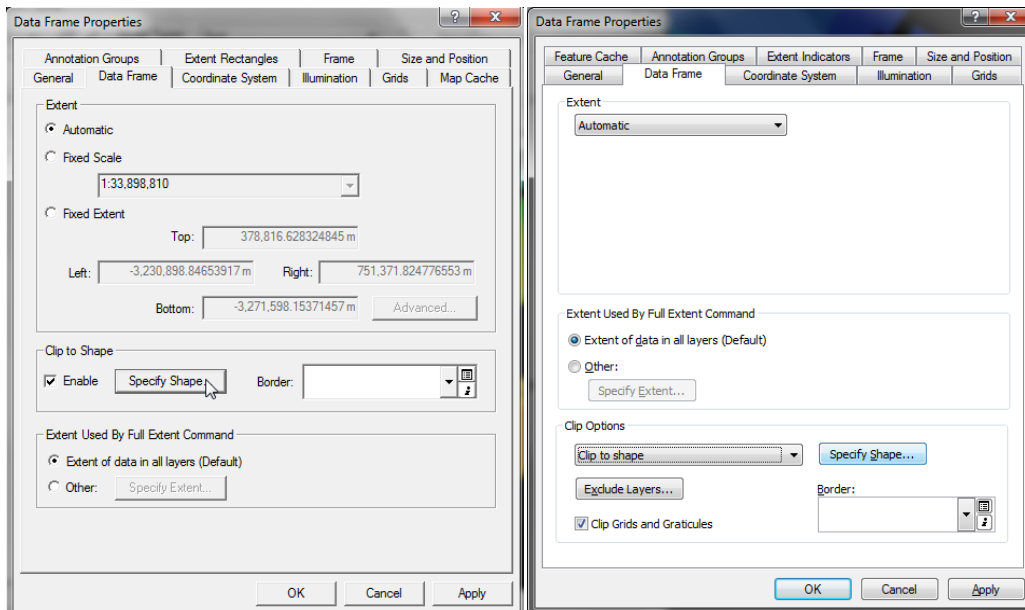
5. Because of the latitude of Greenland, this is not the best projection system to use (why not?). Insert a new data frame in ArcGIS and define the coordinate system to be North Pole Lambert Azimuthal Equal Area.



Rename the data frame to be “Polar projection” or something similar. Then drag your map into that frame. It should look like:

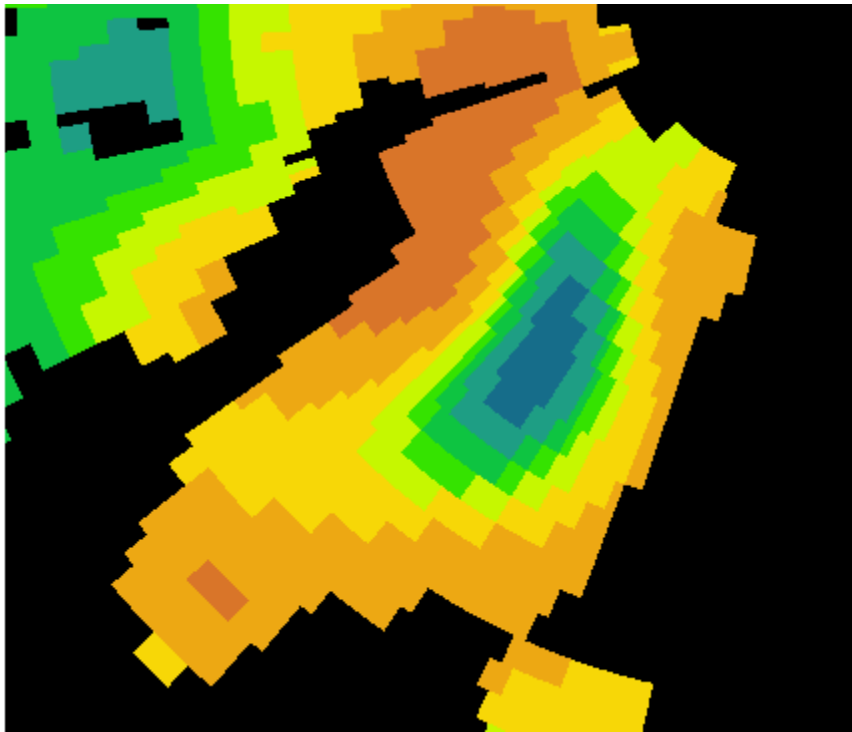


6. Since we are only interested in Greenland we should focus only on the areas of high latitude. Zoom in on the landmass of Greenland. Right click on the data frame, and edit its properties. Click on the Data Frame tab -> Under Clip Options -> Click on Clip to Shape -> Specify Shape.



(Arc 9.3 on left and Arc 10 on right)

Then click on the "Current visible extent" button. Your data frame will now be confined to this area.



Save your .mxd file with an appropriate name.