Lab 1: Projections

OBJECTIVES

This exercise covers map projection, the systematic rendering of the earth's round, three-dimensional surface onto a flat map. Any map projection inherently produces some distortion because only a globe can represent accurately the relative area, shape, and orientation of the earth's surface features. You will use Flex Projector to evaluate various map projections for their major properties and distortions, and understand the importance of selecting projections appropriate for specified land areas or themes when creating a map.

MATERIALS

Flex Projector© Bernhard Jenny, Institute of Cartography ETH Zurich (free software available for download at www.flexprojector.com).

BACKGROUND

Key Terms

Parallel	Line of latitude
Meridian	Line of longitude
Graticule	A network of lines representing a selection of the earth's parallels and meridians.
Developable surface	A surface that can be unrolled onto a plane without stretching or creasing. Three objects that can be developed are a cylinder, cone, and plane.
Conic	Projection onto a cone which has been enveloped around the sphere.
Cylindrical	Projection formed by wrapping a flat plane around the globe to form a cylinder.
Azimuthal	Projection onto a flat plane, also called a planar projection.
Pseudocylindrical	Mathematical projection in cylindrical family with meridians that curve inwards at the poles.
Tangency	Location at which the projection surface and the globe touch.
Secancy	Location at which the projection surface cuts through the globe.
Standard Parallel	Parallel of intersection of the projection surface with the globe

Introduction

One way to understand map projection is to visualize shining a light through a transparent globe with the graticule printed on it. When a piece of paper is wrapped around the globe, the light at the center of it will cast shadows of its graticule onto the developable surface. After the paper is unwrapped, the resulting shape of the graticule on the flat surface will be a distorted version of the globe's graticule. By changing the position of the light source, the shape of the paper, and the orientation of the globe, we can create different projections.

Although thousands of map projections have been derived mathematically, they can be generally categorized by that projection family (*cylindrical*, *conic*, or *azimuthal*) and by their major quantitative property (*conformality* or *equivalence*). Different map projections create different types of distortion in shape, area, distance, or direction properties. All of these properties cannot be preserved on a map, which is why we have more than one projection. No one projection is "best" but some are objectively better for certain purposes.

EXERCISE

Part 1. Orientation and Tangency

A map projection's aspect is its orientation on the developable surface. A projection surface can be positioned over the globe from four aspects: *equatorial*, *transverse*, *oblique*, or *polar*. If oriented with north or south straight up, the aspect is said to be equatorial. When the central axis of the surface is turned 90 degrees from normal, the projection's aspect is transverse. Projections centered on the North or South Pole have a polar aspect. All other orientations have an oblique aspect, lying at an angle somewhere between equatorial and transverse. For most projections, equatorial is the *normal* aspect. A cone is normally oriented so that it is tangent or secant along parallels, while a plane is normally oriented to be tangent at the pole. The line of tangency between a projection surface and the surface of the globe is called the standard line, and if it is along a parallel it is called the standard parallel.

a. What is the difference between equatorial, transverse, and oblique projections?

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b. Where is distortion the least on a map projection?

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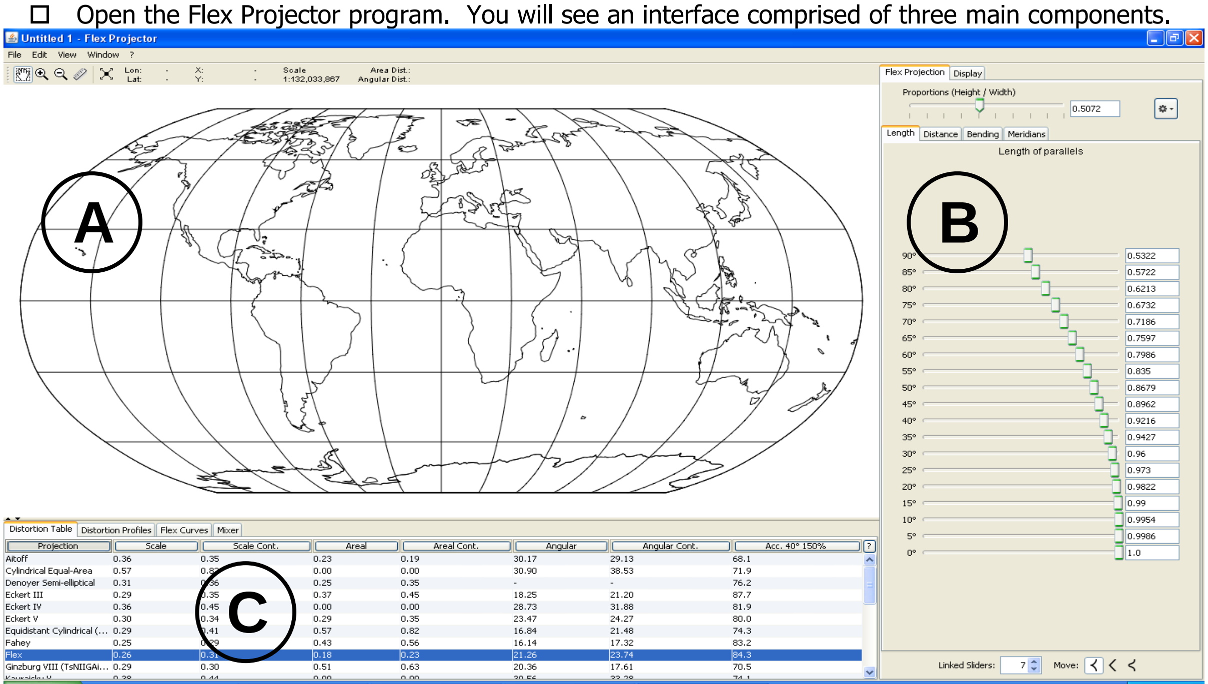
Part 2. Major Properties

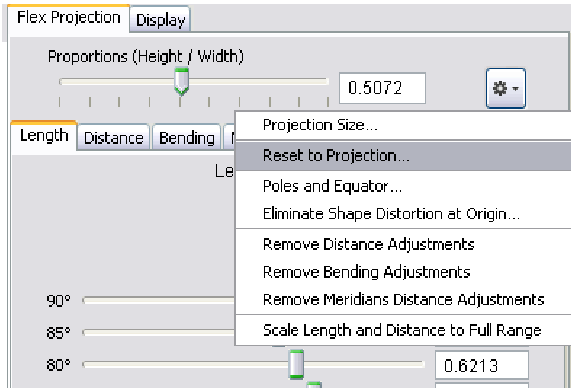
Projections that preserve the property of local shape are called *conformal* projections. On these projections, the lines of the graticule meet at right angles, just as they do on the globe. Conformality is often important in navigation because conformal maps have no angular distortion and therefore local directions can be measured from a given point. Projections that preserve the property of area are called *equal-area*, or equivalent. All parts of the earth's surface are shown with their correct area, as on the sphere or ellipsoid. Equivalence is important for statistical mapping, where comparisons based on area are common. No map can be both conformal and equivalent, and many maps are neither. We will examine these major properties with the use of Flex Projector, a map projection exploration tool. If the program is not installed on your computer, download the free software at www.flexprojector.com.

- ☐ Open the Flex Projector program. You will see an interface comprised of three main components.



A. This pane is a world **map display** in the selected projection. The default is set to the Robinson projection.
B. To the right of the map display is the **Flex Projector panel** with sliders that control the shape of the projection. Moving any of the sliders adjusts the projection in the map display. The four tabs at the top of the panel access sliders for adjusting length of parallels, distance of parallels from the equator, convex or concave bending of parallels, and distribution of meridians.
C. Below the map is the **distortion table**, which reports the amount of distortion contained in the modified projection ("Flex") and allows comparison with other listed projections.

- ☐ Change the default projection from Robinson to Mollweide by clicking the **Options** button in the Flex Projection panel.



- ☐ In the drop-down menu that appears, select **Reset to Projection**.
- ☐ From the pop-up dialog, scroll through the list of projections and select **Mollweide**. The map display will update to the selection.

a. What type of projection is the Mollweide (Cylindrical, Conic, Azimuthal, or Pseudo-cylindrical)?

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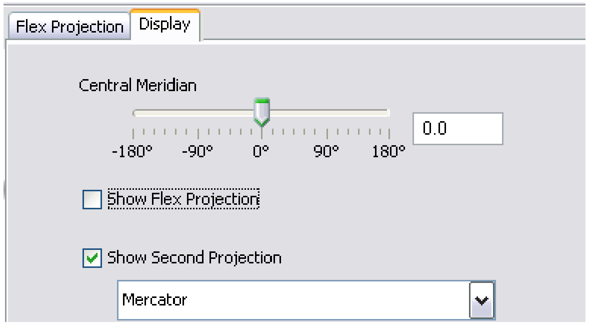
b. What major property does this projection preserve? How can you tell?

- ☐ Return to the Flex Projector panel.
- ☐ Click on the **Display** tab.
- ☐ Check the box next to **Show Second Projection** to enable its display.
- ☐ Click on the drop down beneath it and select **Mercator**.
- ☐ Uncheck the box next to **Show Flex Projection**. The map display will update to a view of the Mercator projection.



c. What type of projection is the Mercator (Cylindrical, Conic, or Azimuthal)?

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d. What major property does the Mercator projection preserve? How can you tell?

Part 3. Distortion

There are two principal forms of map distortion. *Areal distortion* causes different regions on the map to have disproportionate sizes with respect to each other. Distortion of shape technically is called *angular distortion* and typically causes shearing so that map features appear twisted or bent.

Tissot's Indicatrices are a set of circles or ovals drawn at regular intervals on the graticule to graphically illustrate distortions due to map projection. Each indicatrix shows how a circle on the earth's surface appears when its geometry is distorted through projection. The size of the ovals and their slants show where distortion occurs. In conformal projections, in which angles are preserved at all locations, the Tissot's indicatrices are all circles with varying sizes. In equal-area projections, the Tissot's indicatrices have the same area, although their shapes and orientations vary with location.

- ☐ On the Flex Projector Panel, disable the second projection so that only the Mollweide is shown in the map display.
- ☐ Check the box for to enable display of **Tissot's Indicatrices**, a set of ovals on the map that show distortion created by the projection.

a. Examine the Tissot's Indicatrices for the Mollweide projection. Describe the ovals that you see. How does their size, shape, or orientation vary as you look toward the poles from the equator?

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b. Where does the most distortion occur?

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- ☐ In the Distortion table, click on **Areal** to rank the projections in descending order of areal distortion.

c. Where does the Mollweide projection fall on the list?

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- ☐ Click on **Angular** to rank the projections by angular distortion.

d. Where does the Mollweide fall on the list?

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- ☐ Now, turn off the Mollweide and enable the Mercator projection.

e. Examine the Tissot's Indicatrices for the Mercator projection. Describe the ovals that you see. How does their size, shape, or orientation vary as you look toward the poles from the equator?

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f. Where does the most distortion occur?

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- ☐ In the Distortion table, click on Areal to rank the projections in descending order of areal distortion.

g. Where does the Mercator projection fall on the list?

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- ☐ Click on Angular to rank the projections by angular distortion.

h. Where does the Mercator fall on the list?

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- ☐ In the Flex Projector Panel, recheck the box next to **Show Flex Projection** to display both the Mollweide and Mercator projections at once.

i. Compare and contrast the two projections. Describe the appearance of the Americas in both projections. Be sure to identify any elongation or stretching in a particular direction, as well as compression in certain latitudes. Also discuss the differences in the appearance of the Tissot's Indicatrices and graticule lines.

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j. Which projection would you use to display world population density?

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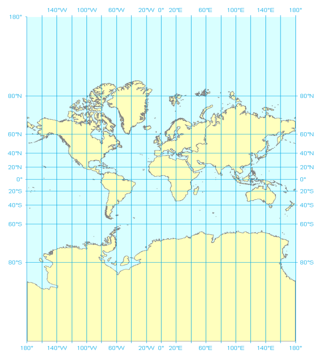
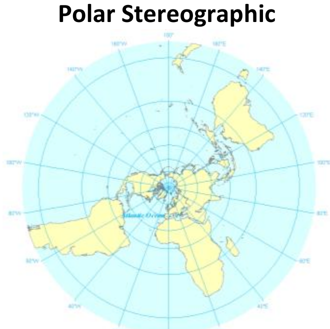
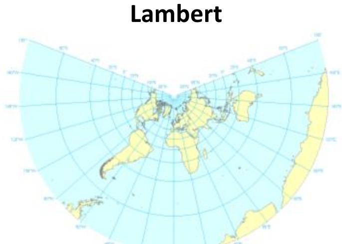
- ☐ In the menu bar at the top, select **File > Export Map (All Currently Visible Elements)**.
- ☐ In the window that appears, choose to export the file as a JPG and press OK.
- ☐ Choose a location on your computer or jump drive to store the file, and press OK. Accept the default pixel width.

k. Attach your JPG to the back of this lab.

Part 4. Projections Table

a. Fill in the table with the developable surface, aspect, and the major property the projection preserves. Use your textbook and the information in the Flex Projector Distortion Table to help you.

Projection	Development Surface (cylindrical, conic, azimuthal)	Aspect (equatorial, transverse, oblique, polar)	Major property (conformal, equal area, compromise)
Mercator 			
Transverse Mercator* 			
Polar Stereographic 			
Lambert 			

***Bonus question: Study the UTM projection. Discuss its secant properties. Where is the least distortion?**

Part 5. Design a projection

You are a cartographer that would like to map the percent of deforestation in the Americas. Decide which type of projection (conformal or equal-area) is appropriate for this map, and use Flex Projector to design a projection that minimizes its distortion.

- ☐ To begin, in the Flex Projector Panel, disable the Mercator display.
- ☐ Click on the Flex projection tab, and adjust the sliders in the Length, Distance, Bending, and Meridian tabs to create your projection.

a. Which major property did you choose to preserve? Why?

b. Your projection appears in the Distortion table as "Flex." What are the values of areal and angular distortion of your projection?

c. Attach a JPG of your projection to the back of this lab.

RELATED LINKS

Snyder, John P. Map Projections: A Working Manual. USGS Professional Paper. 1987.
http://pubs.er.usgs.gov/usgspubs/pp/pp1395
International Cartographic Association Commission on Map Projections.
http://www.csiss.org/ica-map-projections/
Van Wijk, Jarke. Unfolding the Earth: Myriahedral Projections. Eindhoven University of Technology.
http://www.youtube.com/watch?v=b1xXTi1nFCo

REVIEW QUESTIONS

1. Why can't a flat map be a perfect representation of Earth?
2. What do we call the pattern of lines of latitude and longitude on the map?
3. What is the globe and shadow analogy of map projections?