36-315: Statistical Graphics and Visualization

Lab 9
Date: March 12, 2002 **Due: start of class March 18, 2002**

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1 Introduction

This lab will introduce you to the basic map functions in S-PLUS and some of the map projections discussed in class.

To start using the map functions in S-PLUS, type

```
library(maps)
```

For the special functions in this lab, you should also download and source the file `map.s` from the class software page. The command for drawing maps is `map`. The simplest use is to draw the entire U.S., with state boundaries or with county boundaries:

```
map("state")
map("county")
```

To draw individual states, you give a second argument:

```
map("state","michigan")
map('county', 'new jersey')
```

Notice that some states, like Michigan, are composed of multiple disconnected parts. It is possible to select regions in fancy ways; see the documentation on `map` for details.

2 Projections

The default projection is rectangular: longitude is `x` and latitude is `y`, which distorts areas, shapes, and distances. For the rest of this lab, we will examine alternative projections for the continental United States.

First some terminology:

- Circles of equal latitude are *parallels*. The equator has latitude 0.
- Lines of equal longitude are *meridians*. The Prime Meridian has longitude 0.
- In any projection, only some lines can be *true*—have the same length as on the globe of corresponding scale—all other lines are too long or too short. The construction of a projection usually begins with laying out the parallels or meridians which have true lengths.

  Question: In a rectangular projection centered on the equator, which parallels are true? Which meridians are true?

Alternate projections are specified via the `map` parameters `projection`, `parameters`, and `orientation` (which can be abbreviated as `proj`, `par`, and `orient`). For example, the Mercator projection can be specified simply by `proj='mercator'`. You can get details about the names and parameters of the various projections via

```
?mapproject
```

To understand what the projections are doing, it is useful to overlay a latitude-longitude grid on the map. To do this, first save an un-transformed map into a variable `m`. Then every time you make a US map you can call `map.grid`:

```
m <- map('state')
map('state',proj='mercator')
map.grid(m,col=2)
```

Some projections require parameters to be specified. For example, the Cylindrical Equal-Area projection must be given a center parallel. This is provided by `par`:

```
map('state',proj='cylequalarea',par=40)
```

If you add a grid, you can see that the Mercator and Cylindrical Equal-Area projections are similar to the rectangular except the parallels are unevenly spaced. The Mercator spreads the high parallels while Cylindrical Equal-Area spreads the low parallels.

3 Conic projections

In a conic projection, the parallels are circles centered on the North Pole. A cone can be made tangent to any chosen *standard parallel*, or a secant through two standard parallels. All of these projections therefore require one or two latitude parameters. The simplest projections are `conic`, requiring one parameter, and `simpleconic`, requiring two. To specify two parameters, make a vector, e.g. `c(10,90)`.

In a conic projection, only the standard parallels are true, and none of the meridians are true. The meridians are straight lines emanating from the North Pole which are spaced truly on the standard parallel but not on the other parallels.

> **Question:** Submit code which makes a U.S. map with `conic` projection. Choose the parameters to minimize distortion. You probably cannot tell from looking at the map whether it is distorted; you have to rely on the definition of the projection. Do the same for `simpleconic`.

These simple conics do not preserve area. As before, we can obtain variants by changing the spacing of the parallels. The Albers projection is a secant projection that uses uneven spacing to preserve area. It is often used for U.S. maps.

> **Question:** Make an Albers projection of the U.S. List some visible differences between the rectangular projection of the U.S. and the Albers projection. For example, the appearance of specific states. Submit your code and both maps.

The Bonne projection takes a different approach to preserving area. The parallels are equally spaced, but the meridians are not straight—they bulge out from the center.

4 Azimuthal projections

Azimuthal projections are good for focusing on a particular point, the center of projection. All points equally distant from the center point will be equally distant on the map also. The center point is specified via the `orient` parameter, in the form of `c(latitude,longitude,rotation)`. `rotation` is simply used to rotate the map. Perhaps the most useful of these projections is `azequalarea`, which perserves areas.

> **Question:** Submit code to make an Azimuthal Equal-Area projection of the U.S. centered on New York City (41° N and 74° W). Note that the center of projection will not necessarily be the center of the map.

You can decorate the above map by plotting a circle on New York City. To do this, you need to convert from (longitude, latitude) to screen coordinates. The function `mapproject` does this. It remembers the projection used to make the map, so you can just say

```
points(mapproject(longitude, latitude),col=3)
```

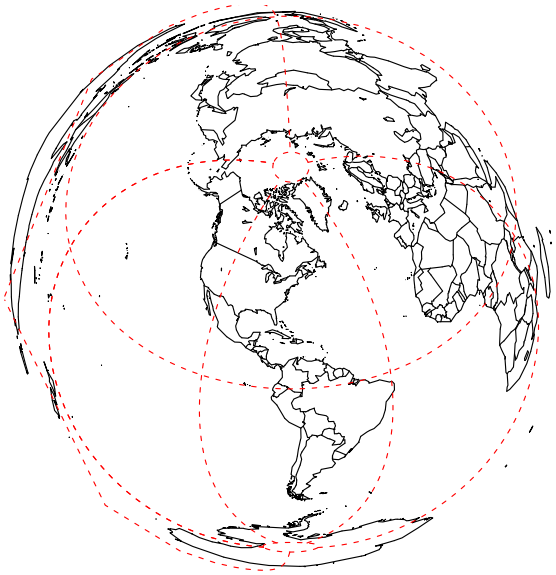
Now try some fancier decoration:

```
text(mapproject(state.center),state.abb)
```

Here is a handy reference table for some of the projections in S-PLUS:

Cylindrical	Preserves
`rectangular`	
`mercator`	Direction
`cylequalarea`	Area
Conic	
`conic`	
`simpleconic`	
`albers`	Area
`lambert`	Shape
`bonne`	Area
Azimuthal	
`azequalarea`	Area
`azequidistant`	Distance
`orthographic`	

Azimuthal projections are useful for mapping the entire globe. Here is what an `azequalarea` projection centered on New York City looks like:



Compare it to a 3D orthographic projection (`orthographic`):