Map Projections

The basic problem is how to map a 3D world onto a 2D computer screen or sheet of paper. An attempt to do so will lose something. There is no self-evident way to present this material.

A map projection is capable of preserving some but not all of the following:

1. Distance
   * The ratio of map distance to real world distance is constant or very nearly so throughout the map
   * The 'scale' is not a laughable approximation
2. Direction
   * Also known as 'angle'
   * This means 'north' on the map always means real world north. Moreover, this applies to other directions like 'north east', which is a 45° angle in the clockwise direction from the y-axis, and the origin of the map.
3. Area
   * The ratio of map area to real world areas is a constant
   * A term like 'equal area' might be used
   * "equivalent" projection
4. Shape
   * An equilateral triangle in the real world will be an equilateral triangle on the map
   * There is no promise here of constant area ratio however
     + The triangles can be similar, and not area preserving
       - Shape preserving does not imply area preserving or conversely

Note: a map is 'conformal', if it preserves angles and shapes, at least in local areas.

Note: a globe preserves all the above and is conformal. No flat map serves as well.

The Globe

Meridians are halves of great circles through both poles. They are specified relative to the Prime Meridian that goes through Greenwich, England. This meridian has 'degree zero", and the whole set is specified as ranging from -180 degrees to +180 degrees, or as 180deg W to 180deg E. The meridians are evenly spaced in terms of angles measured from the center of the earth, but the distance between them is a function of distance from the equator.

**Meridians** are measurements of longitude.

**Parallels** are measurements of latitude. The equator is at 'degree 0'.

The parallels range from -90° (South Pole) to 90° (North Pole). They are equally spaced in terms of angles, and are also equally spaced therefore in terms of real world surface distance on the map. Because the circumference of the map is 25,000 miles, and the pole to pole distance is half that, the typical map of the entire world is usually twice as wide as it is tall.

The globe is roughly spherical, but slightly squashed at the poles (i.e. an ellipsoid). But there is considerable variation in altitude since no one sanded it down to a perfect orb. The term **geoid** is sometimes used to describe the ultimate global reality, or in its very technical meaning, what the globe would look like at ocean height, if the ocean were extended under land masses in a manner consistent with gravitational forces at each point. Gravitational forces vary from point to point.

The basic (standard) **Mercator projection** is the best known map of the entire globe. The projection is 'cylindrical' (i.e. based on a particular cylinder, and in this case one that wraps neatly around the equator). Technically, the cylinder notion is an approximation, and really an 'inflated sphere' is how it is done, but that is not a big deal.

If one projects from the north south axis in a horizontal direction, the areas and latitudes near the poles would be horribly compressed, and distances in northern realms therefore horribly distorted north to south. The northern parallels are artificially close together. This effect is the same as if you take a picture of the earth from the moon, more or less. The basic Mercator uses the scheme below, or something close thereto.

If one projects from the center of the earth, then the map MUST BE infinite in the vertical direction in order to capture every point except the two poles. This was seen as using too much paper or too many pixels. So one cheats by omitting parts of the two Polar Regions. Nonetheless, the cylinder projected upon is tsller than the poles. There is thus a lot of distortion in the Polar Regions, as well as some omission. The distortion is that east to west distances are enormously stretched as we move north.

Moreover the distance between parallels also increases as we move north.

Distance is true (preserved) on the equator only, and only close to true near the equator. The map is conformal in the small (i.e. if a small area is exploded). The map preserves direction however. A Rhumb Line (i.e. a straight line on the map) is a true direction, but does not correspond to a great circle arc (i.e. distance is not perfect or shortest).

Note: some Mercator maps are viewed is being drawn for a cylinder whose diameter is smaller than the Earth's (e.g. passing through the parallels at 45, -45). This causes less distortion for USA.

In this case distance is true at three parallels: -45, 0, and 45.

This kind of map is called a SECANT Mercator map, since the cylinder intersects the Earth in what is called a secant in your friendly neighborhood calculus class.

Note: the kind of map originally described is a TANGENT Mercator map with the cylinder tangent to the equator.

A transverse Mercator is one where the cylinder is tangent to a great circle through the poles. An oblique Mercator is one where the cylinder is tangent to any other great circle.

Note: sometimes conformal maps are characterized by saying meridians meet parallels at right angles. This is often more or less a true statement and is true in spades about the basic Mercator projection.

Note: it is sometimes asserted that for large maps, conformal and equal-area cannot be achieved simultaneously. I would not know how to prove that.

The basic Mercator is badly NOT equal area. A conic equal area map with the cone point at the North Pole, will have meridians meeting parallels at right angles (at least in terms of tangent lines to arcs representing parallels), but will not preserve direction or shape. The distance between parallels will now tend to decrease with distance from the pole, the opposite effect from the basic Mercator. This map does not tend to preserve shape well at large distances from the pole (i.e. where it counts: populous areas).

Azimuth

* An angle from some axis or ....(various astronomical meanings)

Azimuthal Projection

* Projection onto a plane where the plane is tangent to the earth at some point.
* Also called a planar projection
  + The term 'planner' applied to a surface means 'flat' also.

Aspects / Flavors

1. Polar: plane touches a pole
2. Equatorial: plane touches the equator
3. Oblique: other

The point of projection can be at infinity, or on the globe opposite the point of tangency, or the 'aspect' of a side of a hill is the direction that slope 'faces'; if they are running down a hill (be careful) and facing East, then East is the aspect of your trail.

A **conic projection** is a projection onto a cone which is then sliced and unfolded. The cone can be tangent to a parallel, or oblique or secant or whatever. The usual flavors are possible. The point of projection can be on the globe (e.g. a pole, or 'above' the globe, or whatever).

To understand preservation issues, imagine the area between two consecutive meridians, and two consecutive parallels at about +45. The top and bottom edges will be concave, and the sides will clearly not be parallel, but 'converge' to the North Pole. An equal area map will look much like this sketch. Clearly area and distance are fairly well preserved, but direction is not. Two non-parallel lines cannot both point north. If this area is distorted to a rectangle, clearly area and distance will suffer, but direction will now be preserved. And the map will be regarded as conformal (i.e. LOCALLY preserving shape and direction).

If a projection is onto a plane, the word 'perspective' describes the location of the point which is the center of the projection.

More terms:

1. If the center of the projection is the center of the earth, the projection is **'gnomonic'** (‘gno’ is a root word for 'know'). Such a projection shows great circles as straight lines.
2. If the center of the projection is the point on the earth surface opposite the point of a tangent plane, the projection is **stereographic**
3. If the projection is made from a point at infinity, the projection is **orthographic**
4. rhumb line or loxodrome: a line of constant direction -- it intersects every meridian at the same angle; e.g. if you follow a NE rhumb line from San Diego for a long ways, what point are you guaranteed to reach? Or converge to? The following are the same: line of constant bearing, rhumb line, loxodrome, and the colloquial phrase coming from them: dead reckoning. Whereas "as the crow flies" means a great circle arc.

Summary: azimuthal: projected on a plane, either tangent or secant.

gives a wonderful head start on preserving directions, so sometimes

'azimuthal' means direction preserving. For a planar map, one can

discuss 'perspective', which refers to the projection point.

cylindrical: projected on a tangent or secant cylinder. Such maps

are characterized to looking like rectangles when unfolded. Of course

one could be viciously deceptive and cut a circle out of one.

conic: projected onto a cone; when unfolded these maps tend to

look like a fan. For strategic reasons, the cone point is usually

a pole.

Microsoft interview question: from how many places on the globe can you

walk one mile south, one mile east, and finally one mile north, and be

back where you started?

Geographers describe direction primarily by one of the following methods:

1. Azimuth

2. Quadrant

An 'azimuth' of zero degrees by definition indicates due North. For all

other directions, swing and measure an angle by going clockwise from the

y axis. Thus an azimuth of 90 degrees specifies due East, 180 is due

South, so forth.

There are four quadrants: NE, NW, SE, SW. To indicate a direction pick

the right quadrant and then fine tune. E.g. N 60 deg E is the same as an

azimuth of 60 degrees. E.g. S 30 deg W is the same as an azimuth of 210.

Some oft used projections are these

1. Mercator cylindrical

2. Lambert Azimuthal Equal-Area

3. Albers Conic Equal-Area

4. Robinson compromise projection (tries to distort everything a bit, but

nothing too much)

5. Mollweide elliptical (squishes the globe at the poles with some drama)

6. Sinusoidal equal-area (aka Mercator Equal-Area)

parallels are equally spaced, and inter-meridian distance is

accurately proportional to latitude (uses the cos() multiplier)

7. Peter's equal area, aka Gall equal area

originally done by Jas. Gall, then reinvented by Arno Peters; got

a lot of politically correct press for not making Greenland look as big

as Africa----not loved by cartographers, but worth a Google;

Monmonier, who authored "How to Lie With Maps", says it looks like wet

ragged underwear, hung on the Arctic Circle (rough quote)