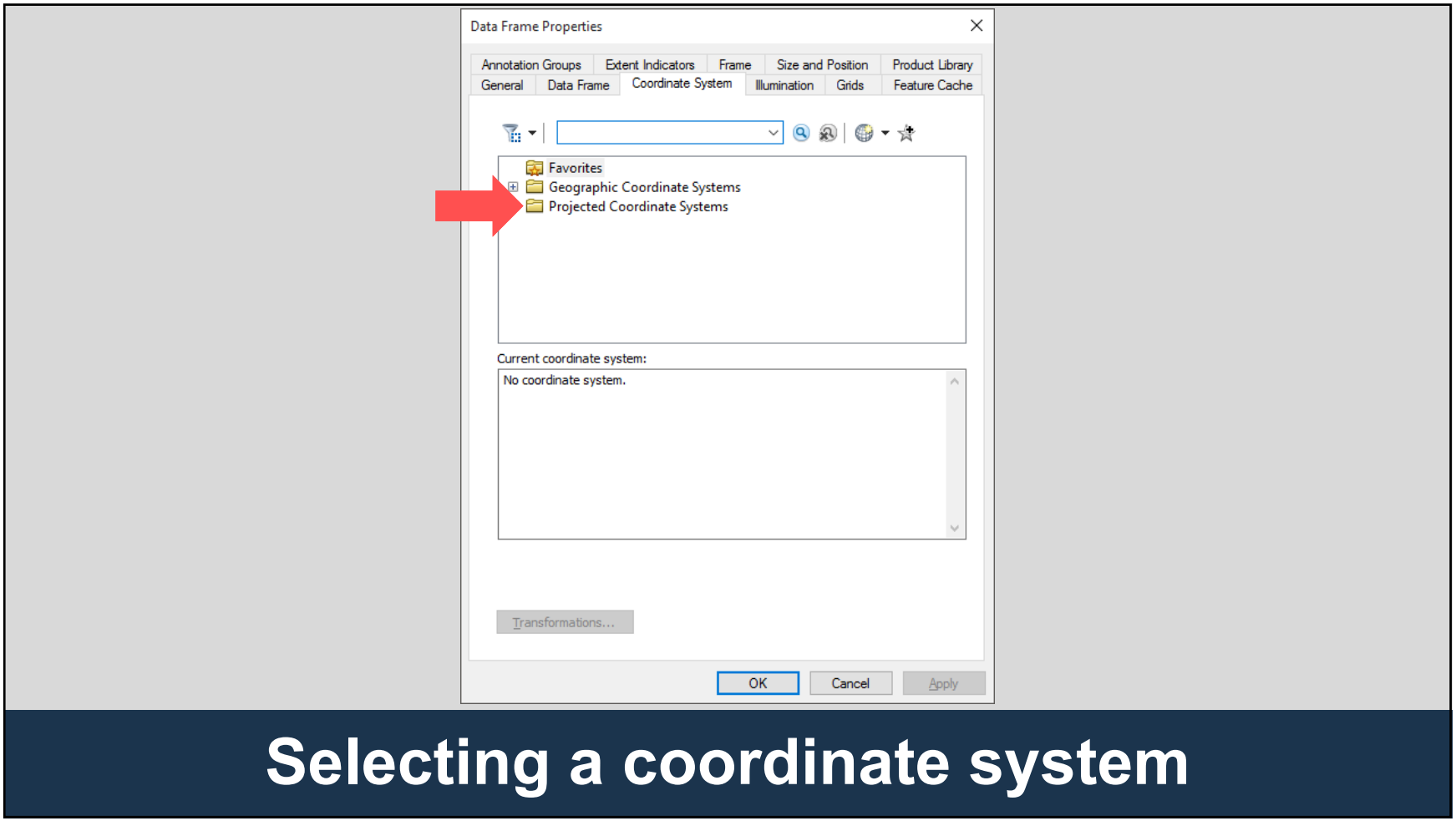
Purpose of map projections



Selecting a coordinate system

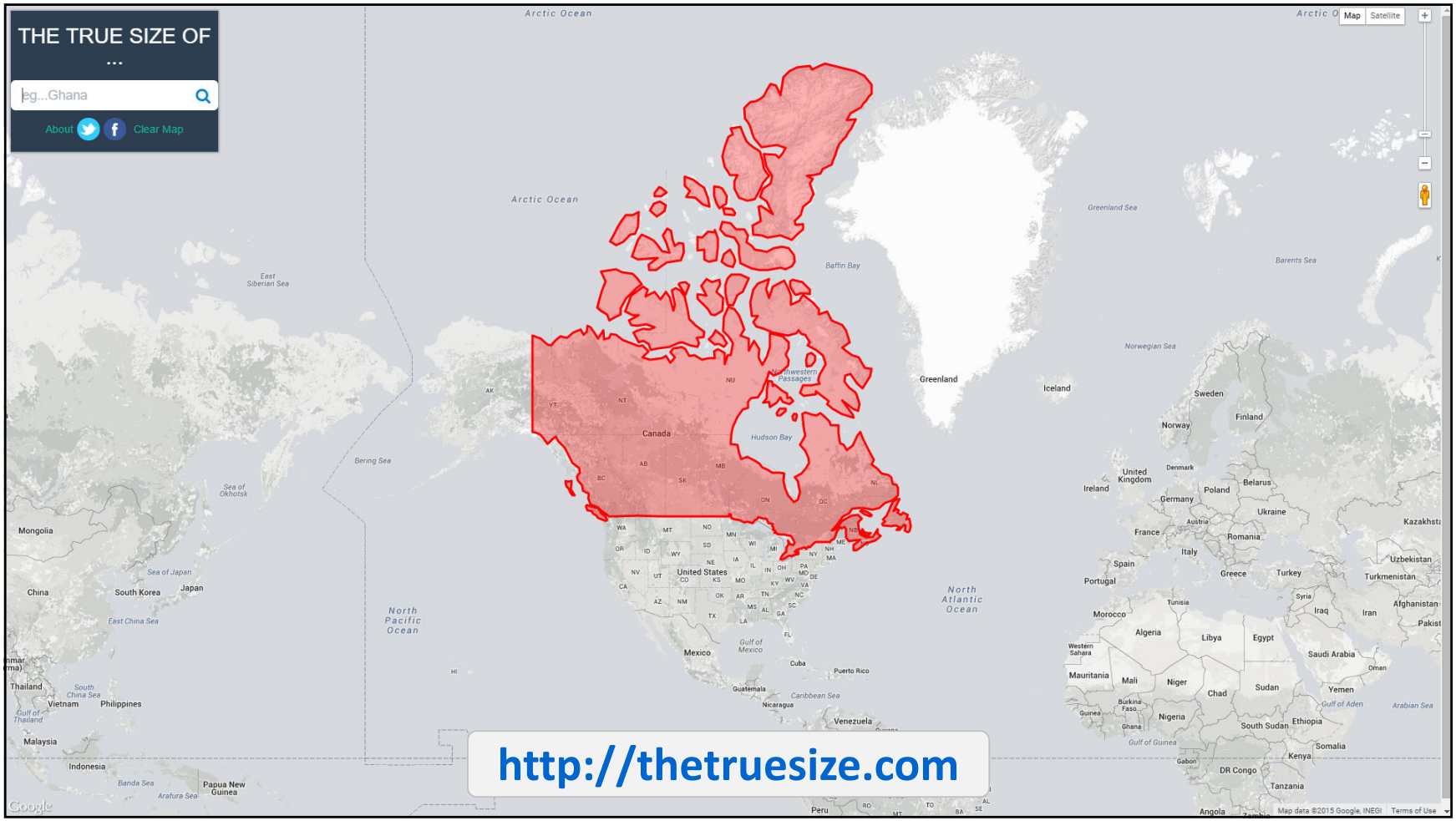
Globe vs. Map

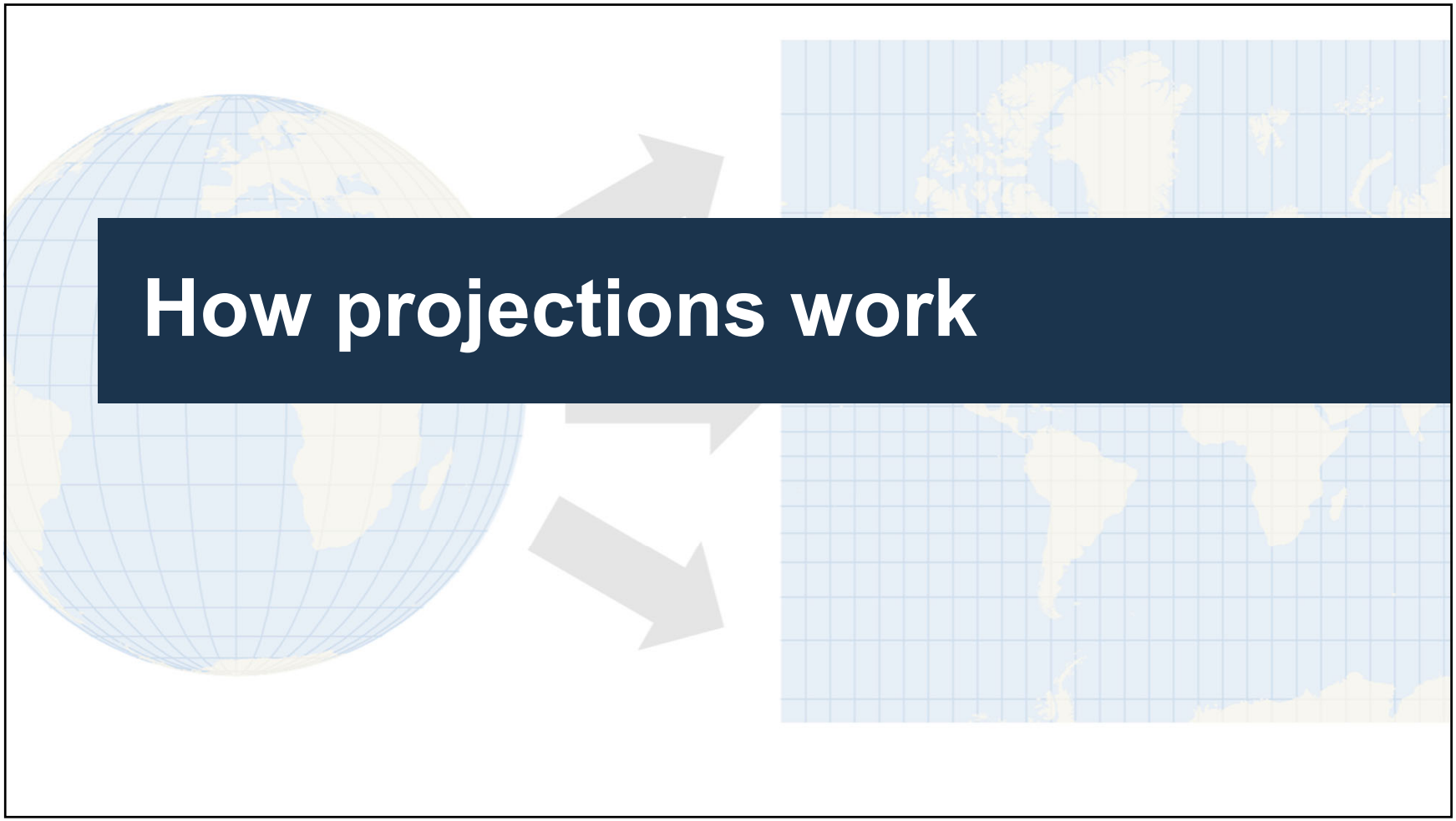
Globe:

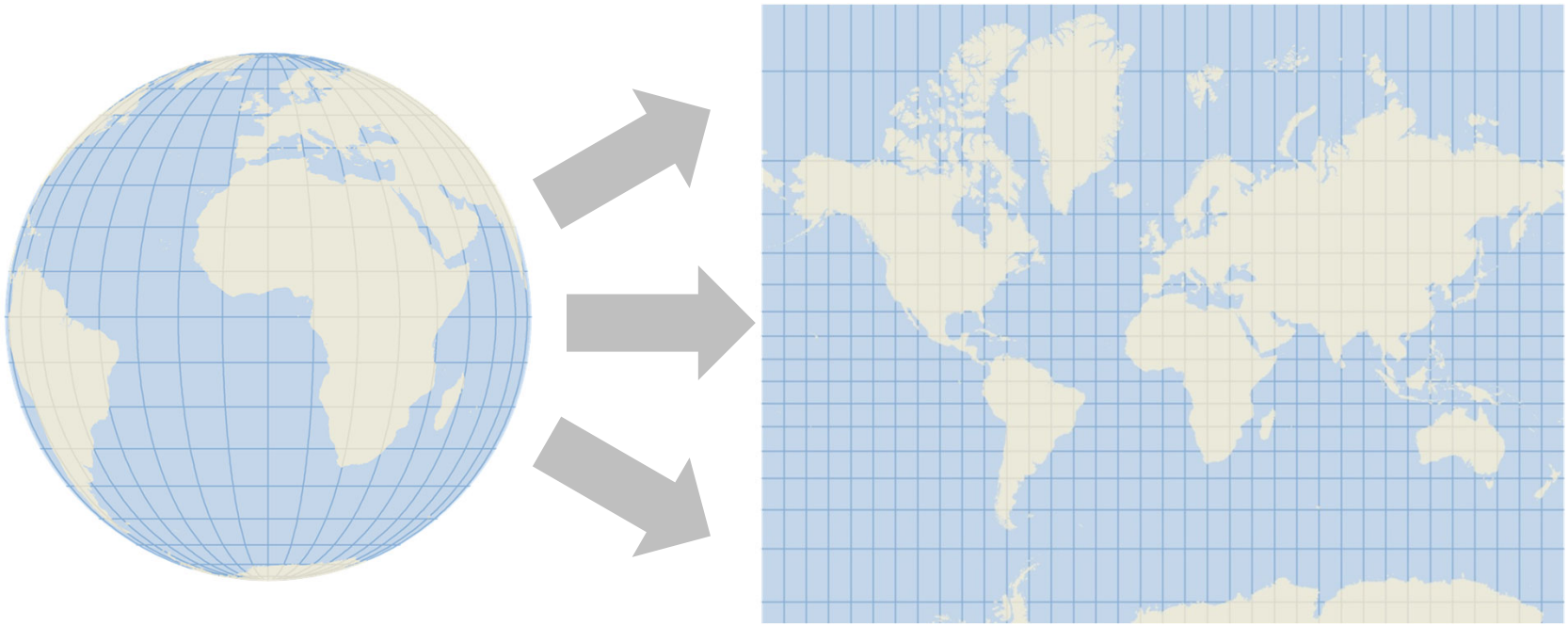
- Three-dimensional (3D)
- Expensive, cumbersome, no detail, but no distortion

Map:

- Two-dimensional (2D)
- Easier to measure distance, area, direction
- Can show more detail
- Easy to work with, portable, cheaper
- Distortion.





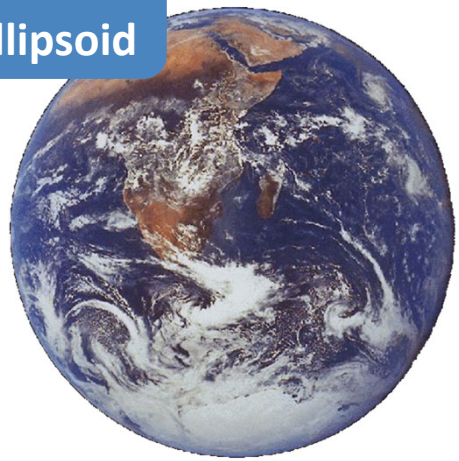


Transformation of 3D Earth to a 2D map

What is a map projection?

First, imagine that the Earth
has been shrunk to the desired scale

Can use either
sphere or ellipsoid



Reference Globe

Full-sized Earth

1:100,000,000
Principal scale

Goal: Flat map with scale of 1:100,000,000

1:100,000,000

Hypothetical

Still 3D

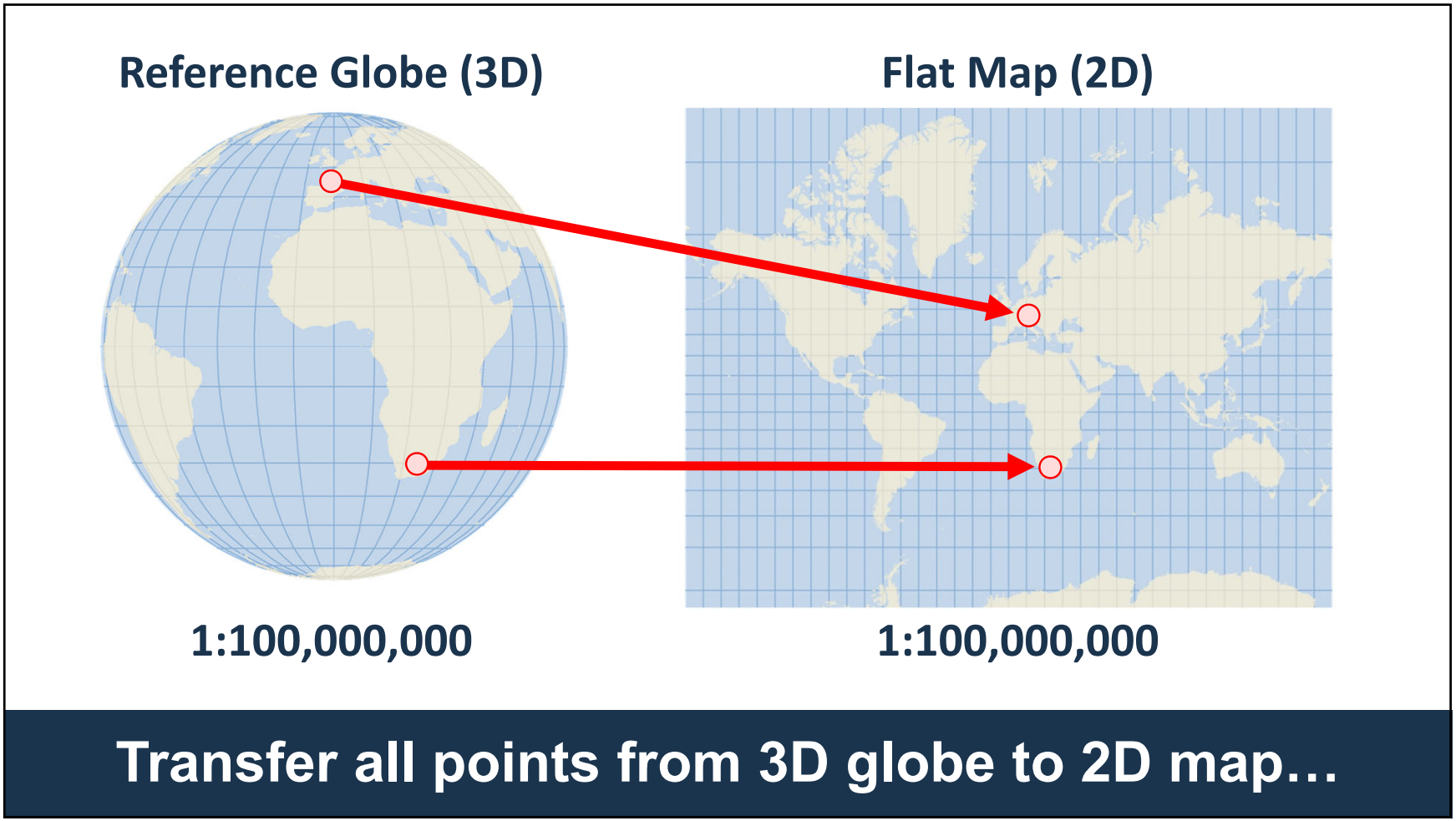
Principal scale = $\frac{\text{Reference globe radius}}{\text{Earth's radius}}$

$$\frac{6.378 \text{ cm}}{637813700 \text{ cm}}$$

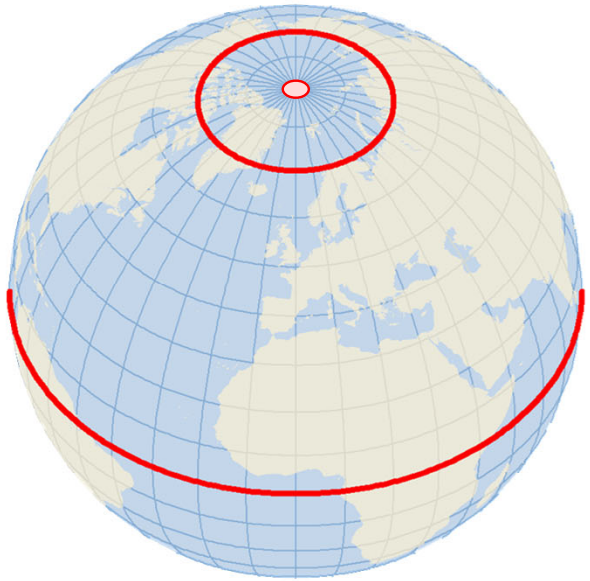
$$= 0.00000001$$

or **1:100,000,000**

Reference globe

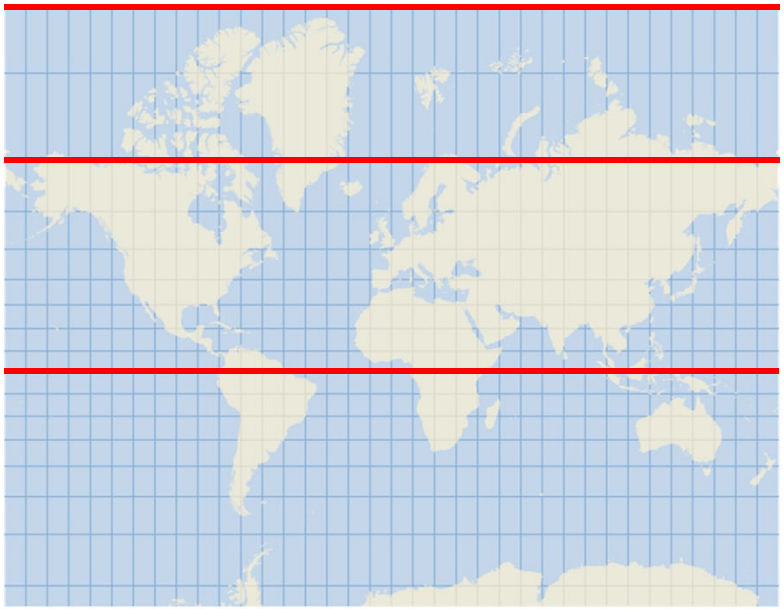


Reference Globe (3D)



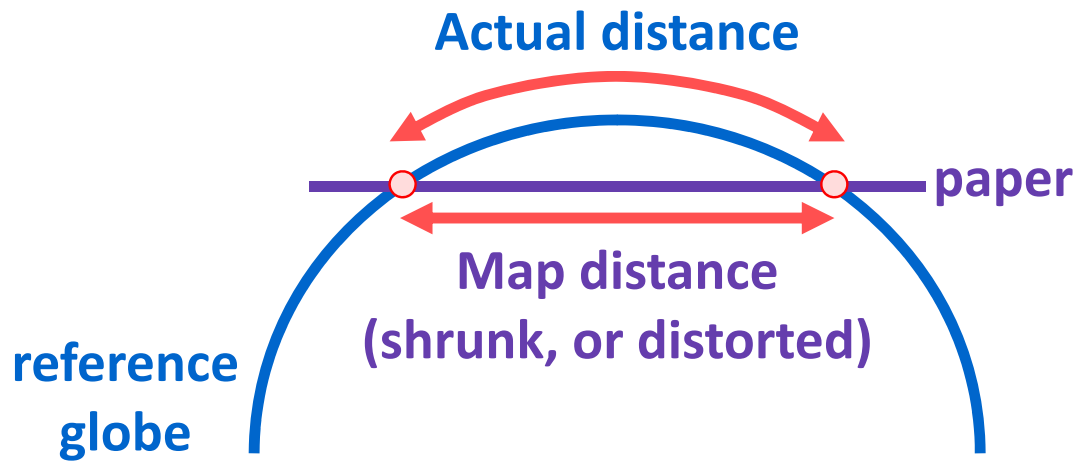
1:100,000,000

Flat Map (2D)



1:100,000,000

Distances are distorted

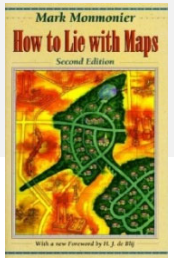


To flatten globe, must stretch, tear, or distort…

(based on Melita and Kopp, 2004)

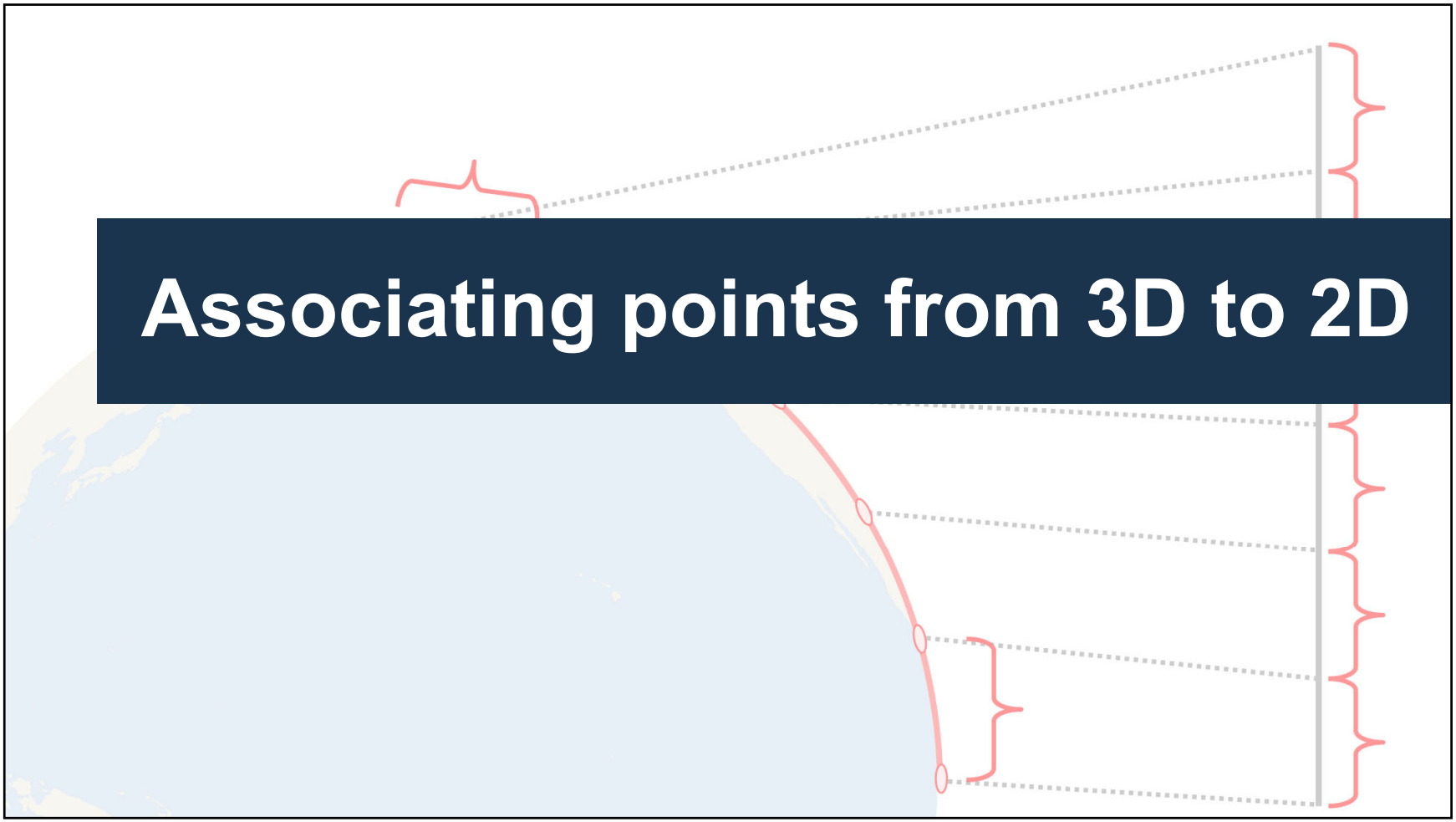
From curved surface to flat

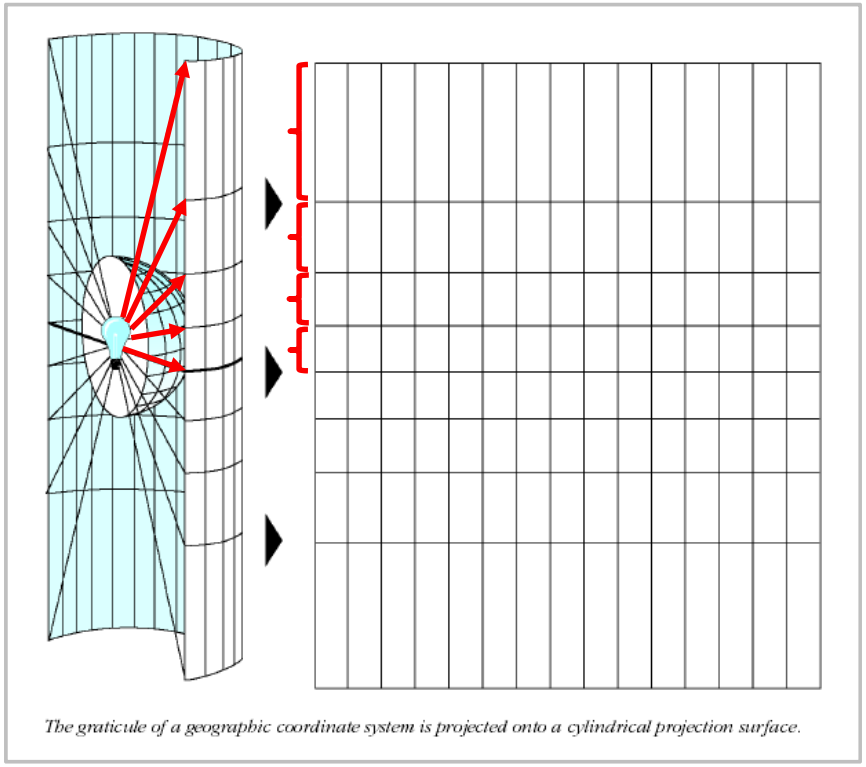
How to lie with maps...



"Not only is it easy to lie with maps, it's essential. To portray meaningful relationships for a complex, three-dimensional world on a flat sheet of paper or video screen, a map must distort reality"

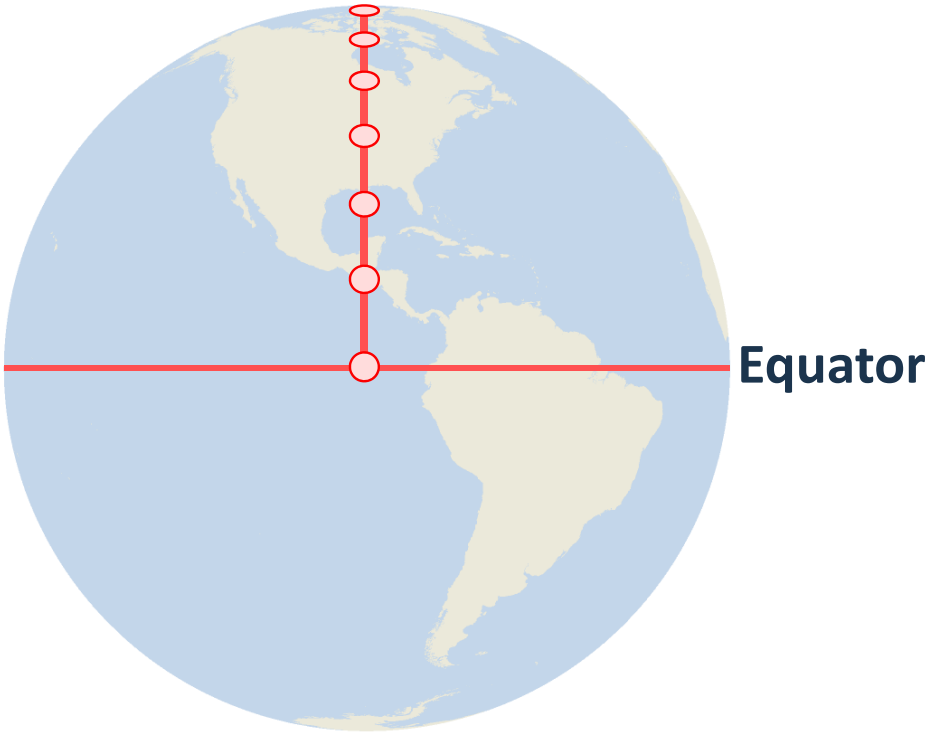
Mark Monmonier, How to Lie with Maps, 1996





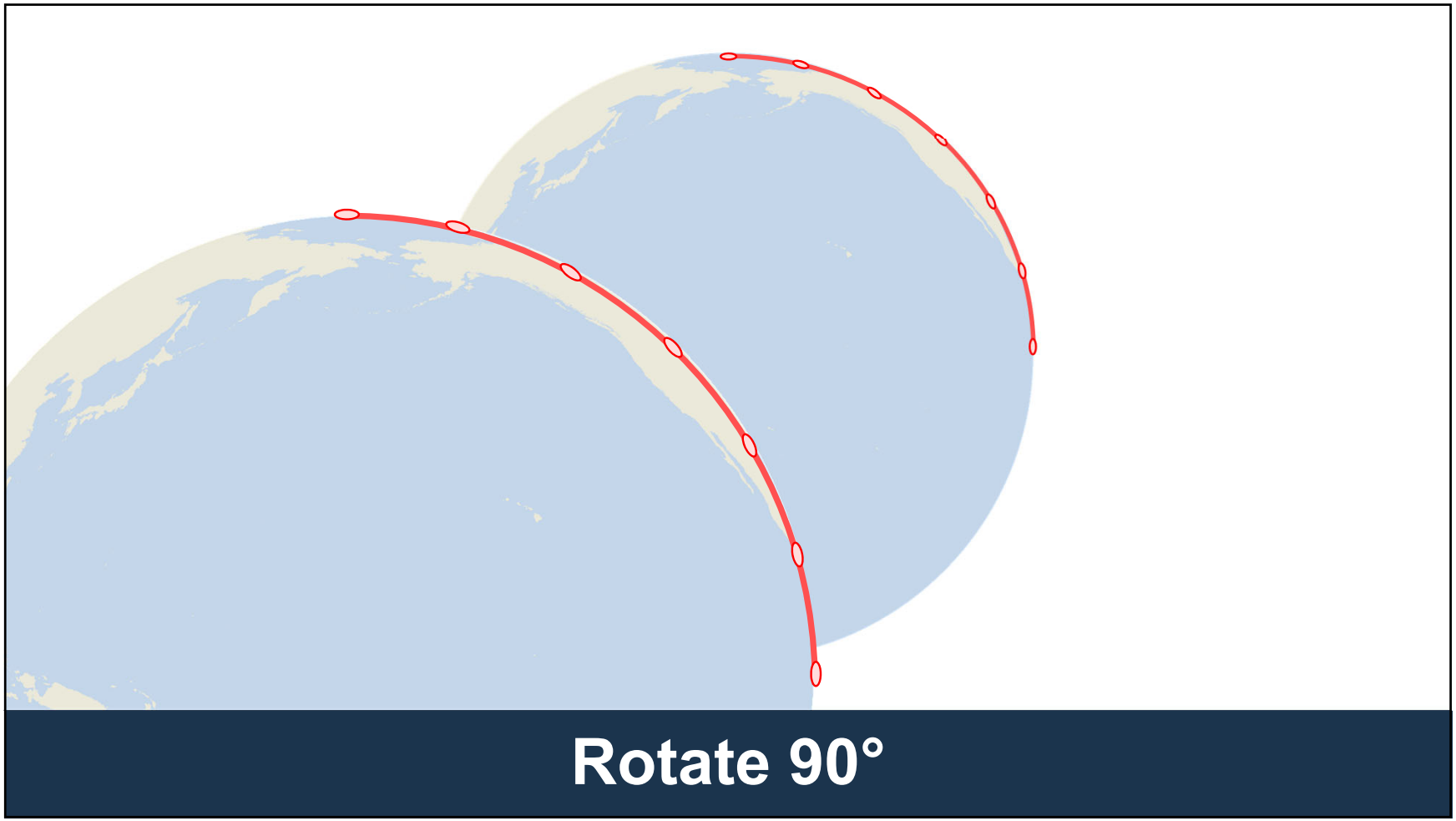
The graticule of a geographic coordinate system is projected onto a cylindrical projection surface.

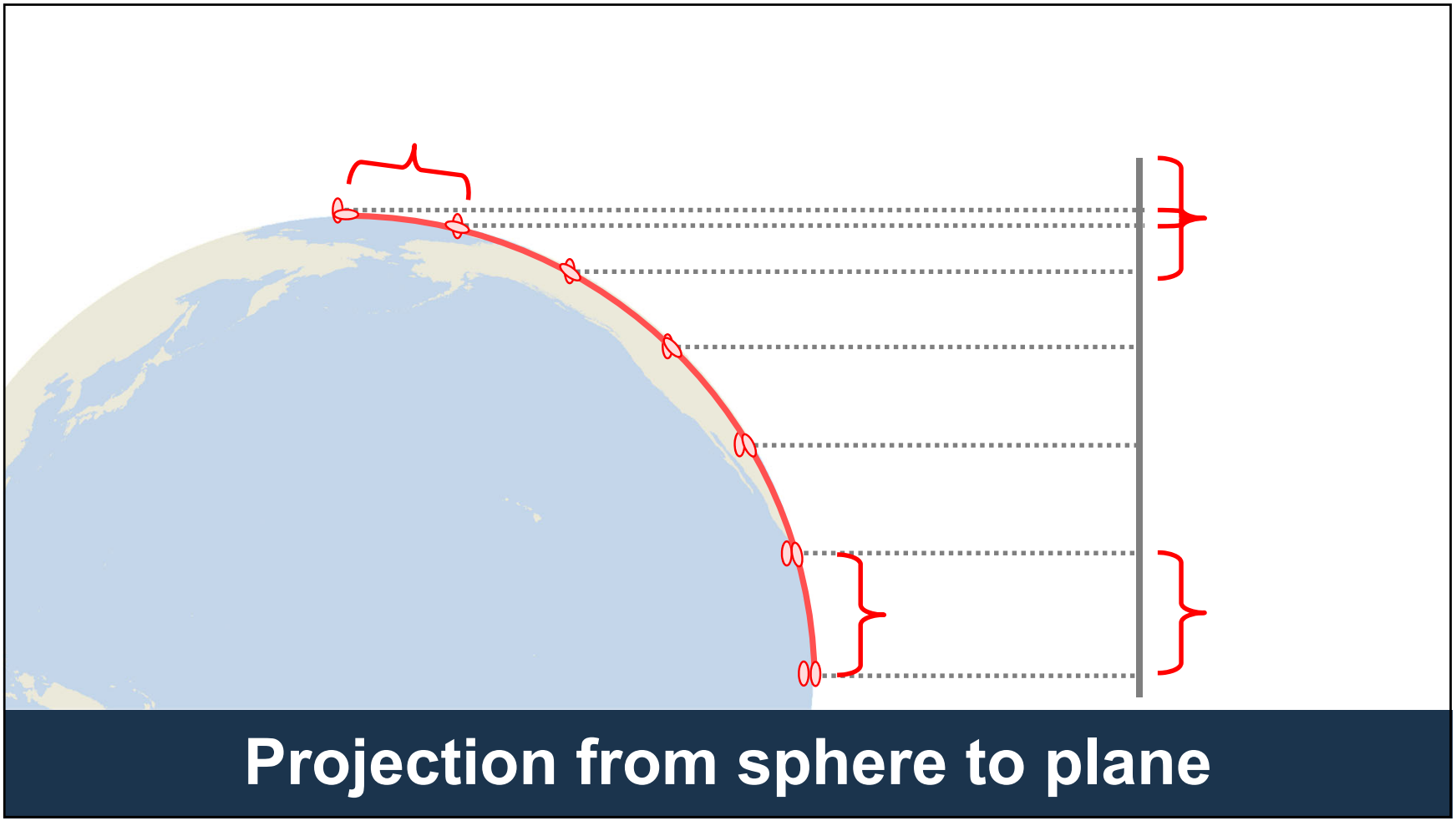
Associating points



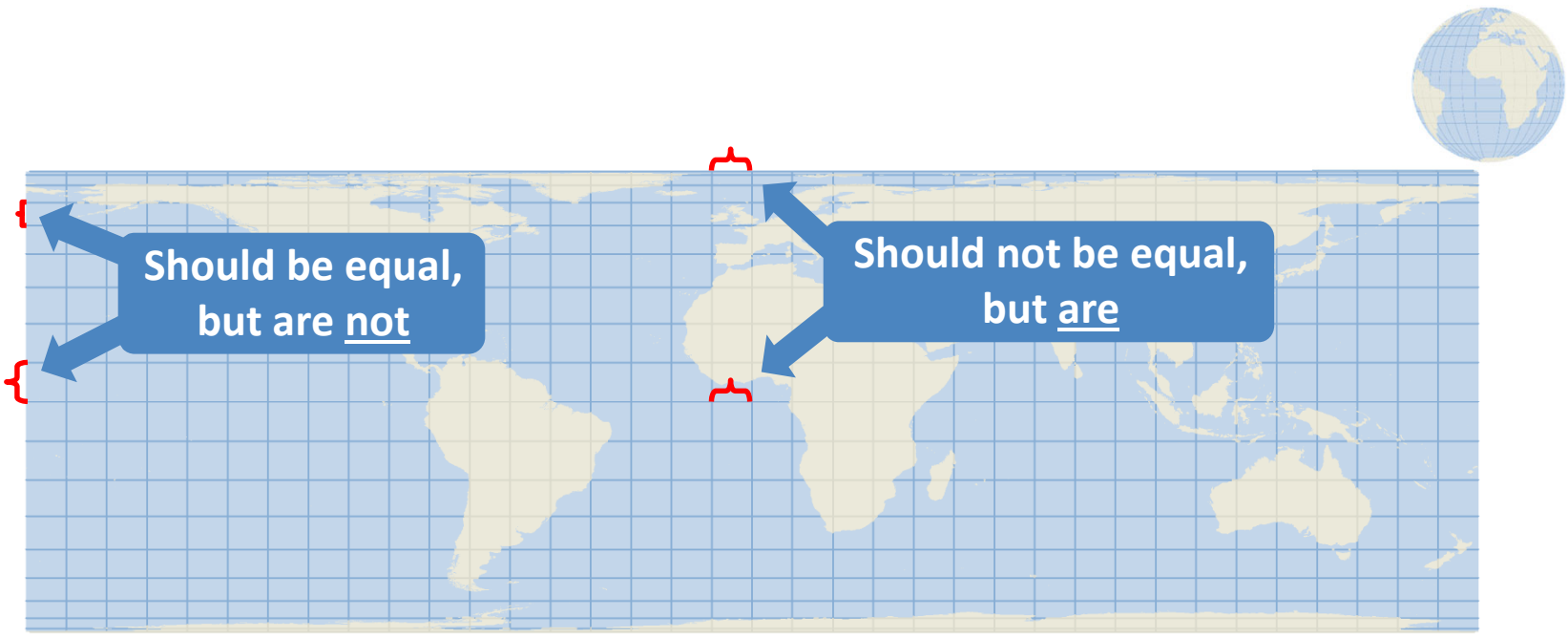
Draw a line from the equator to the pole…

Rotate 90°

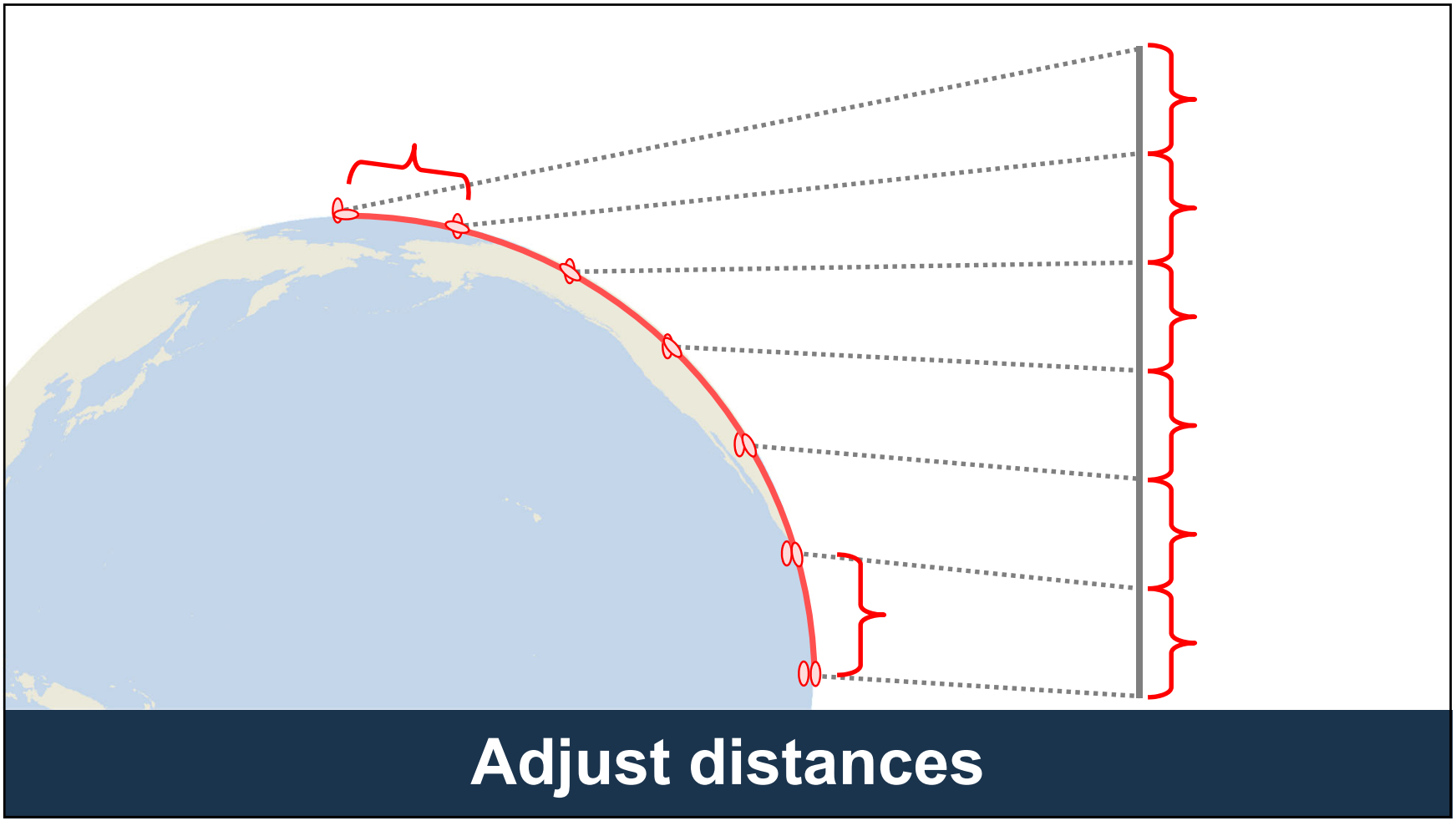




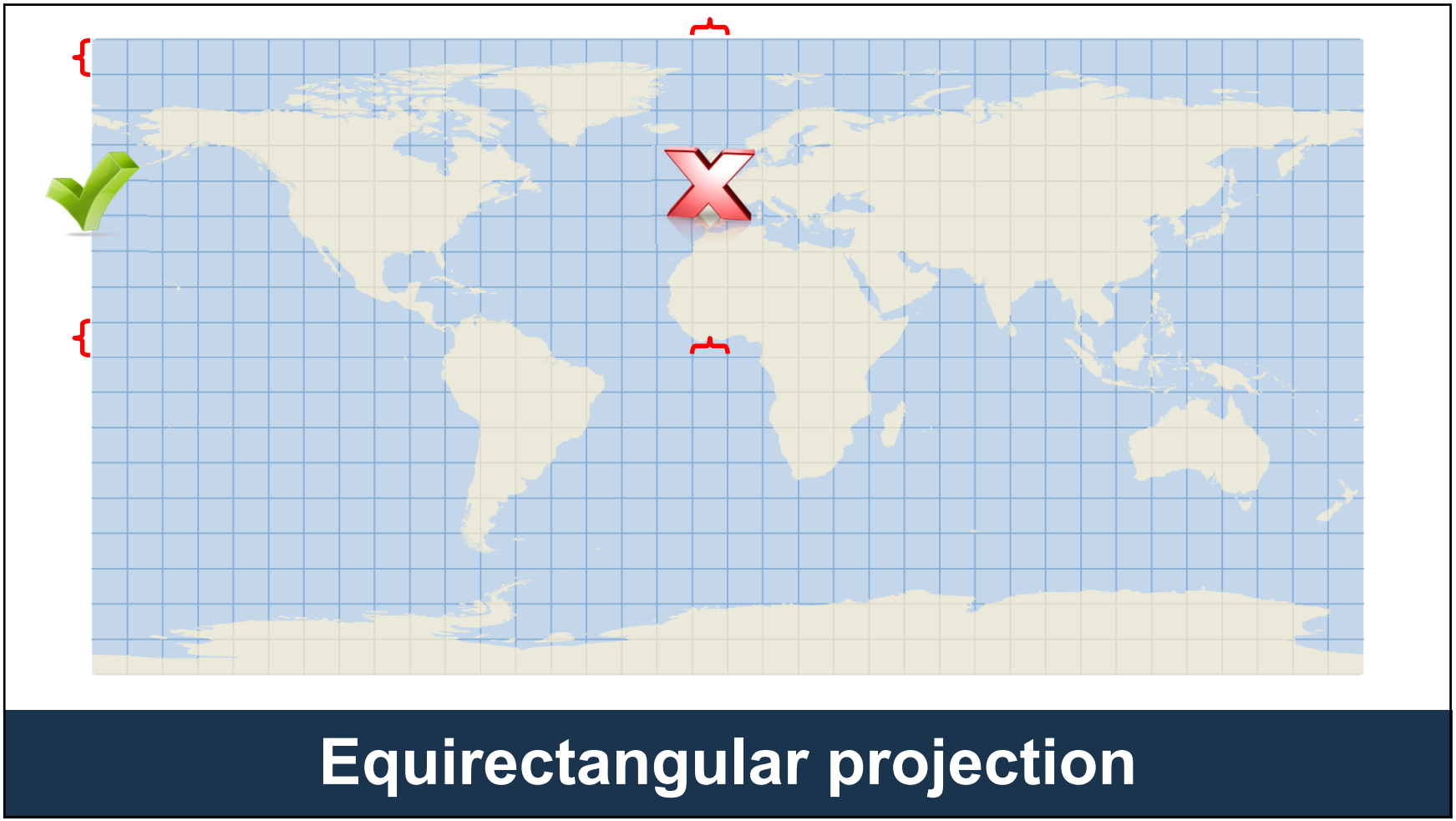
Projection from sphere to plane



Cylindrical Equal Area



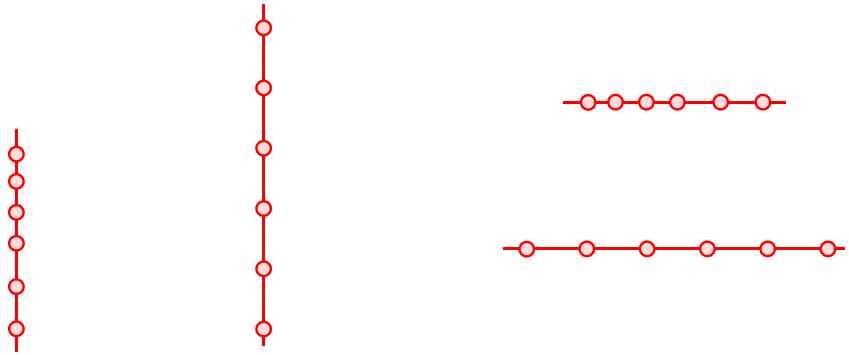
Adjust distances

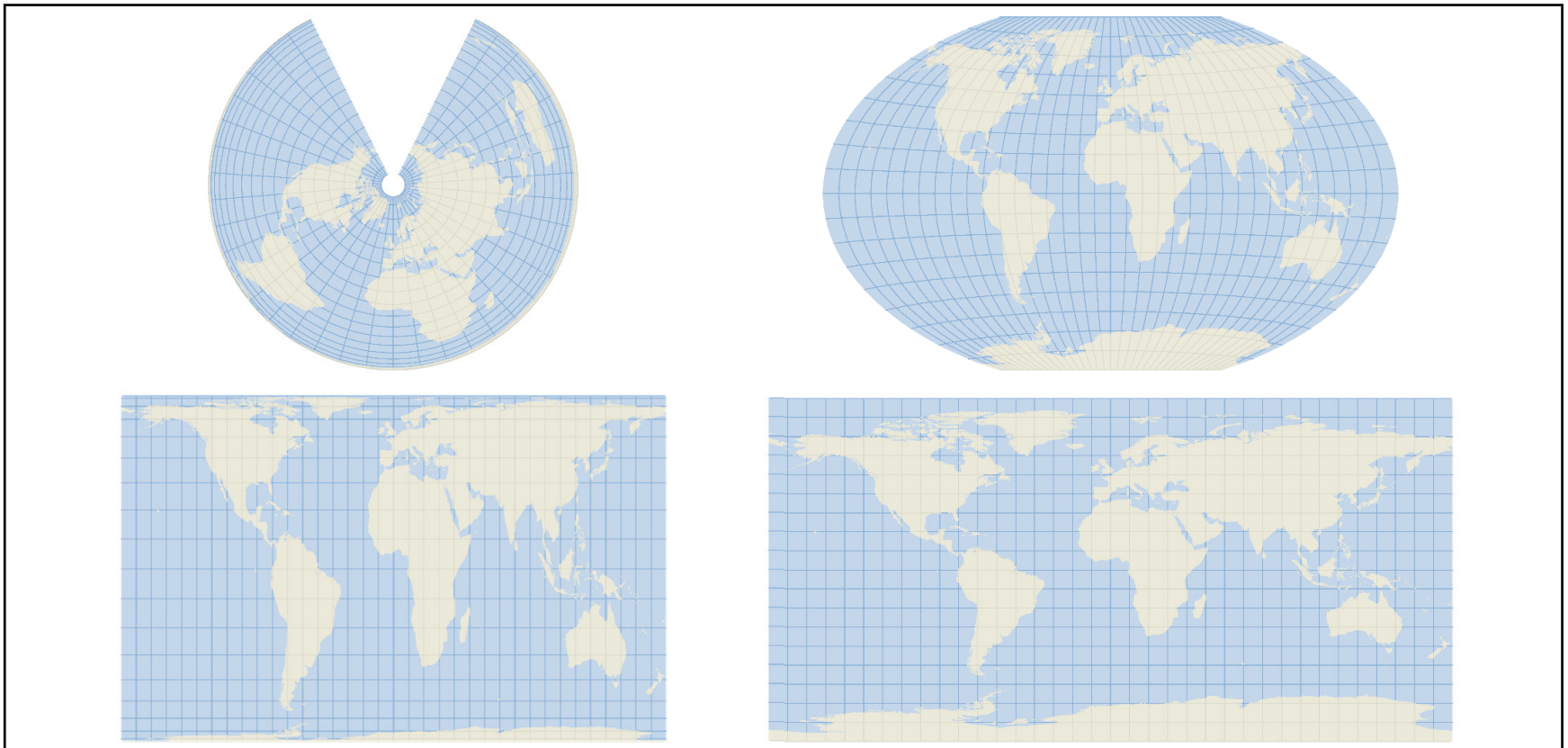


Equirectangular projection

Two perpendicular directions

- We adjusted points along a meridian
- Same can be done along a parallel
- Can adjust both, and in different ways.



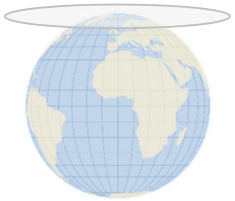


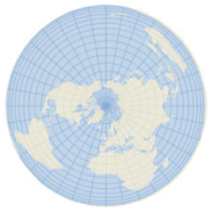
Graticule: indicates how projections work

Projection class (developable surfaces)

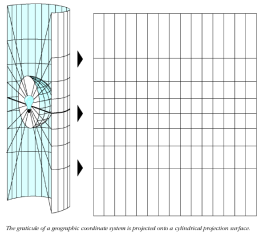
Projection classes

Planar

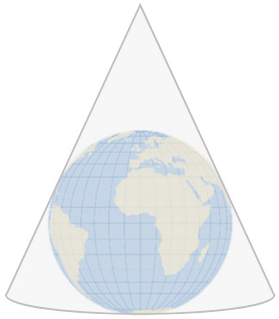


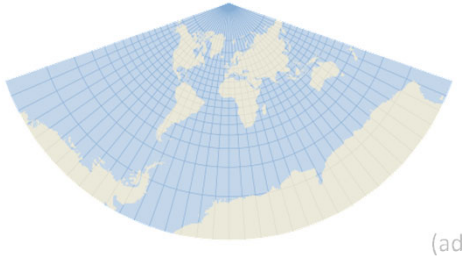


Cylindrical



Conic





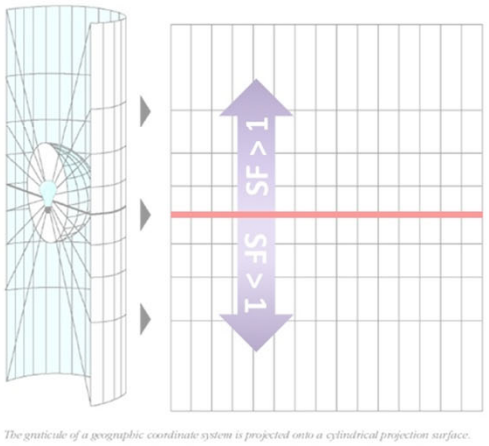
(adapted from Lo and Yeung, 2006)

Standard line and scale factor

$$SF = \frac{\text{Local scale}}{\text{Principal scale}}$$

Scale on map

Scale on



The graticule of a geographic coordinate system is projected onto a cylindrical projection surface.

i.e., where is there no distortion?

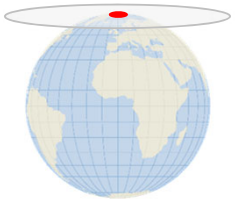
$$SF = \frac{1/100{,}000{,}000}{1/100{,}000{,}000}$$

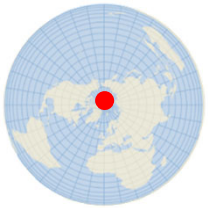
SF = 1 at the standard line

What happens to the SF as you move away from the standard line?

(Kennedy *et al.*, 2004)

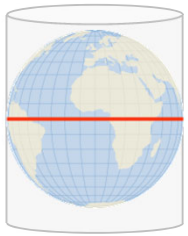
Planar

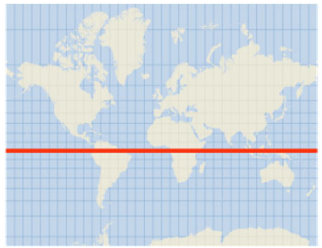


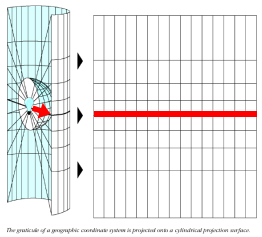


Where globe touches developable surface

Cylindrical

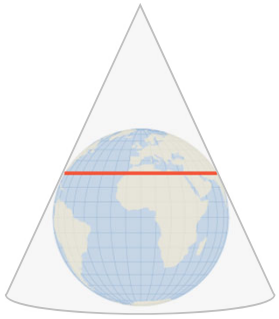


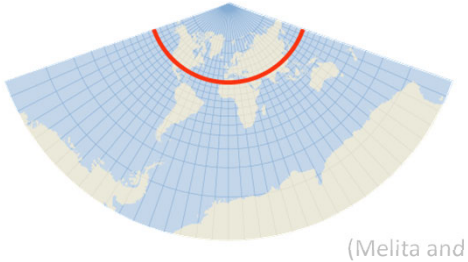




The graticule of a geographic coordinate system is projected onto a cylindrical projection surface.

Conic





(Melita and Kopp, 2004; Lo and Yeung, 2006)

Standard point or line

1:100,000,000

Hypothetical

Still 3D

Principal scale = $\frac{\text{Reference globe radius}}{\text{Earth's radius}}$

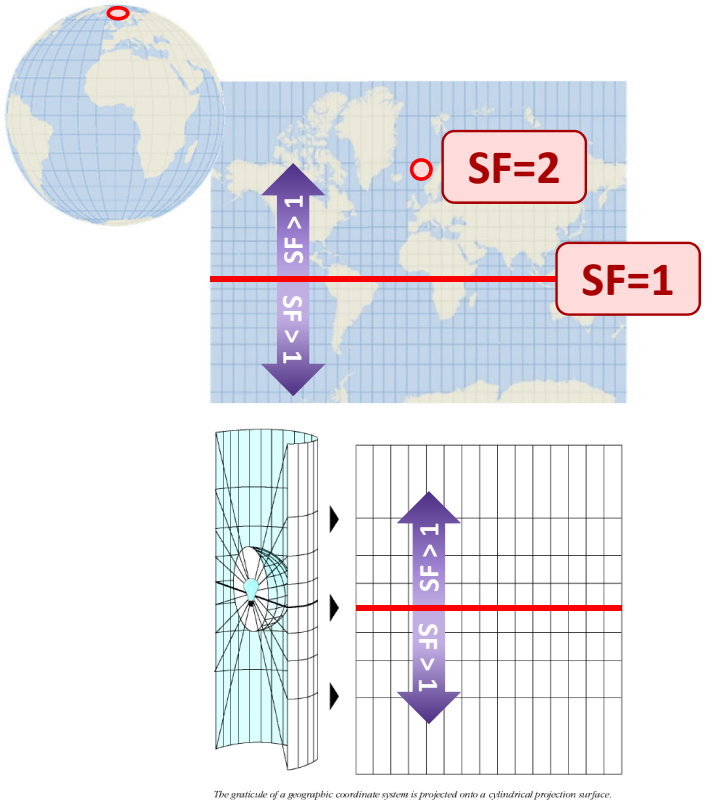
$$\frac{6.378 \text{ cm}}{637813700 \text{ cm}}$$

$$= 0.00000001$$

or **1:100,000,000**

Reference globe

Scale factor



The graticule of a geographic coordinate system is projected onto a cylindrical projection surface.

$$SF = \frac{\text{Local scale}}{\text{Principal scale}}$$

Scale on map

Scale on ref. globe

Where will the local scale be the same as the principal scale? i.e., where is there no distortion?

$$SF = \frac{1/100{,}000{,}000}{1/100{,}000{,}000}$$

SF = 1 at the standard line

What happens to the SF as you move away from the standard line?

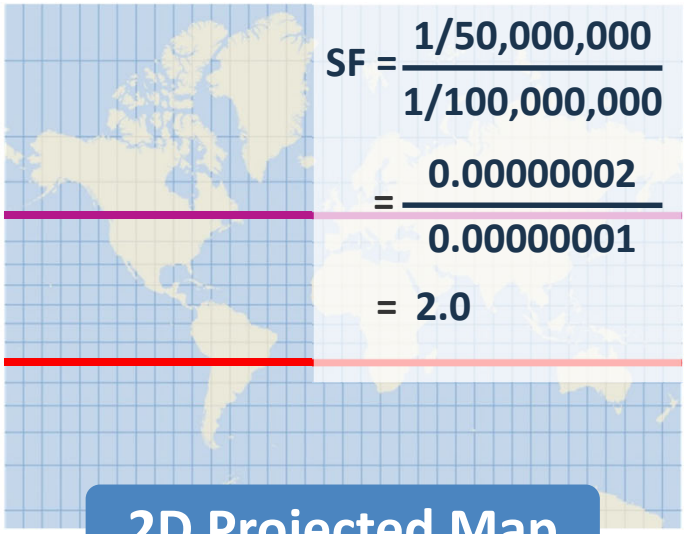
(Kennedy *et al.*, 2004)

No distortion (3D)

3D Reference Globe

1:100,000,000
(at all locations)

Scale factor varies

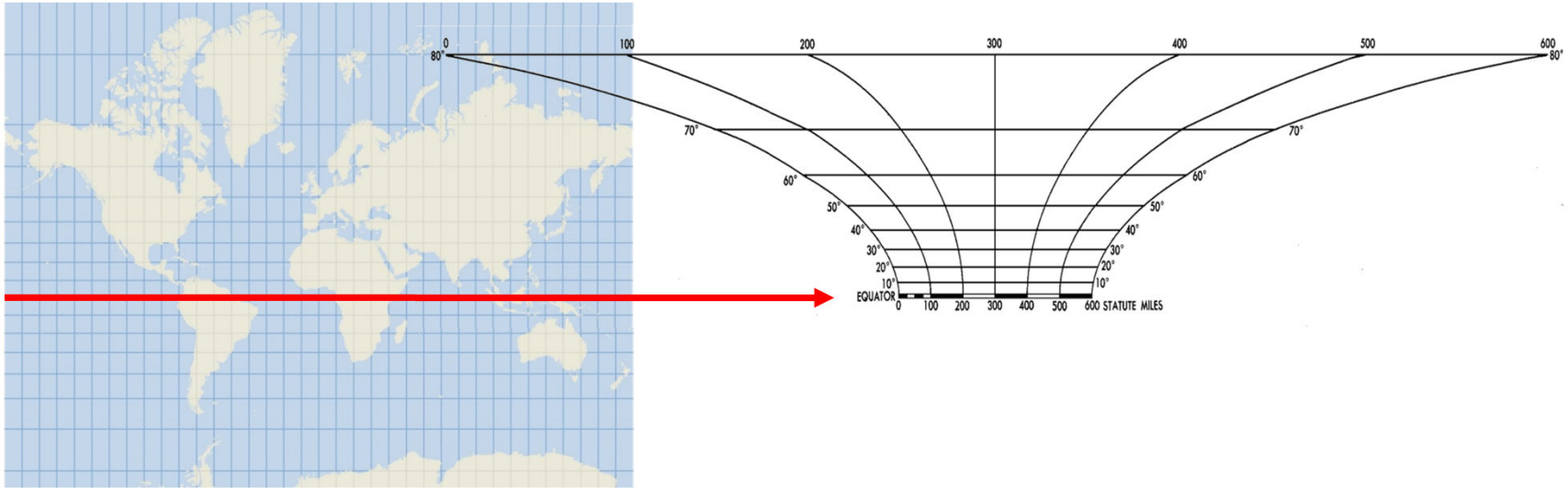


2D Projected Map

1:100,000,000
(only along standard line)

(Kimerling *et al.*, 2009)

Scale factor



http://en.wikipedia.org/wiki/Mercator_projection

Variable scale bar

1:500,000

Representative fraction

(absolute scale)

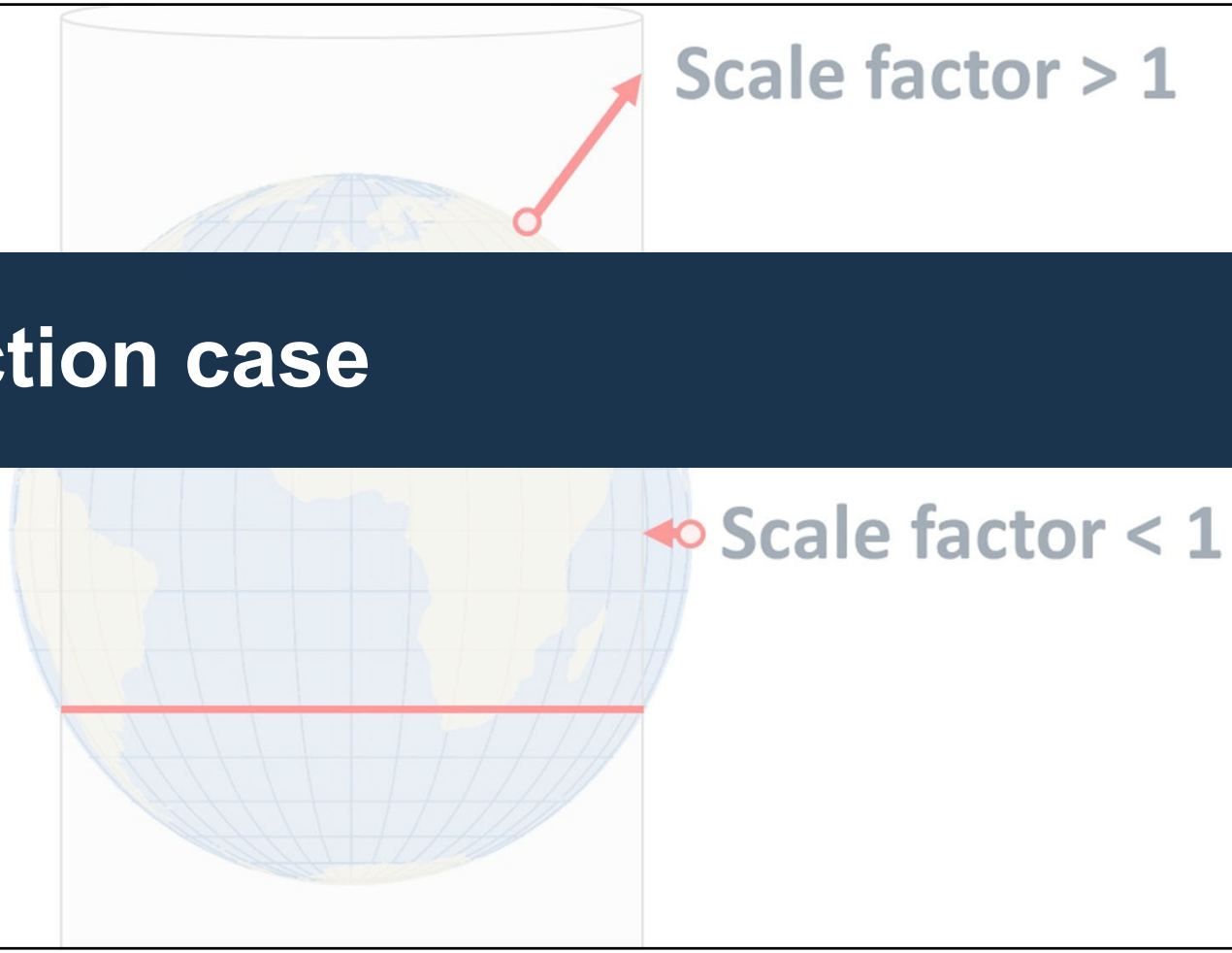
“one inch to one mile”

Verbal scale

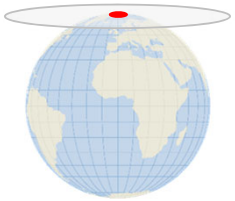
> 1:250,000

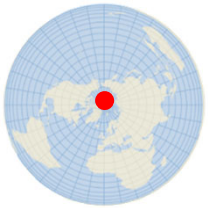
Bar scale

Projection case



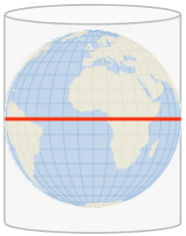
Planar

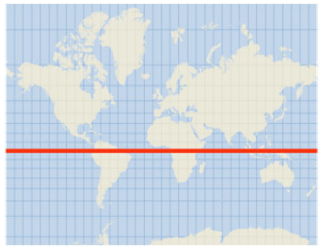


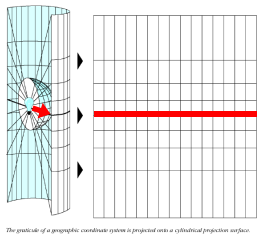


Scale factor = 1
at standard lines

Cylindrical

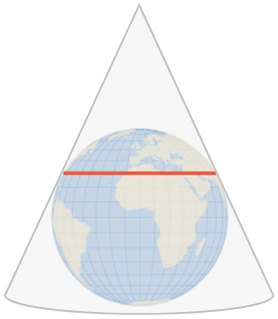


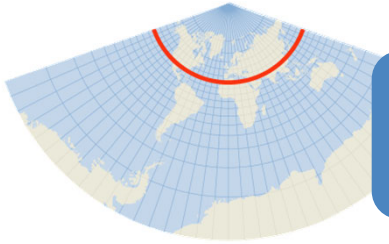




The graticule of a geographic coordinate system is projected onto a cylindrical projection surface.

Conic

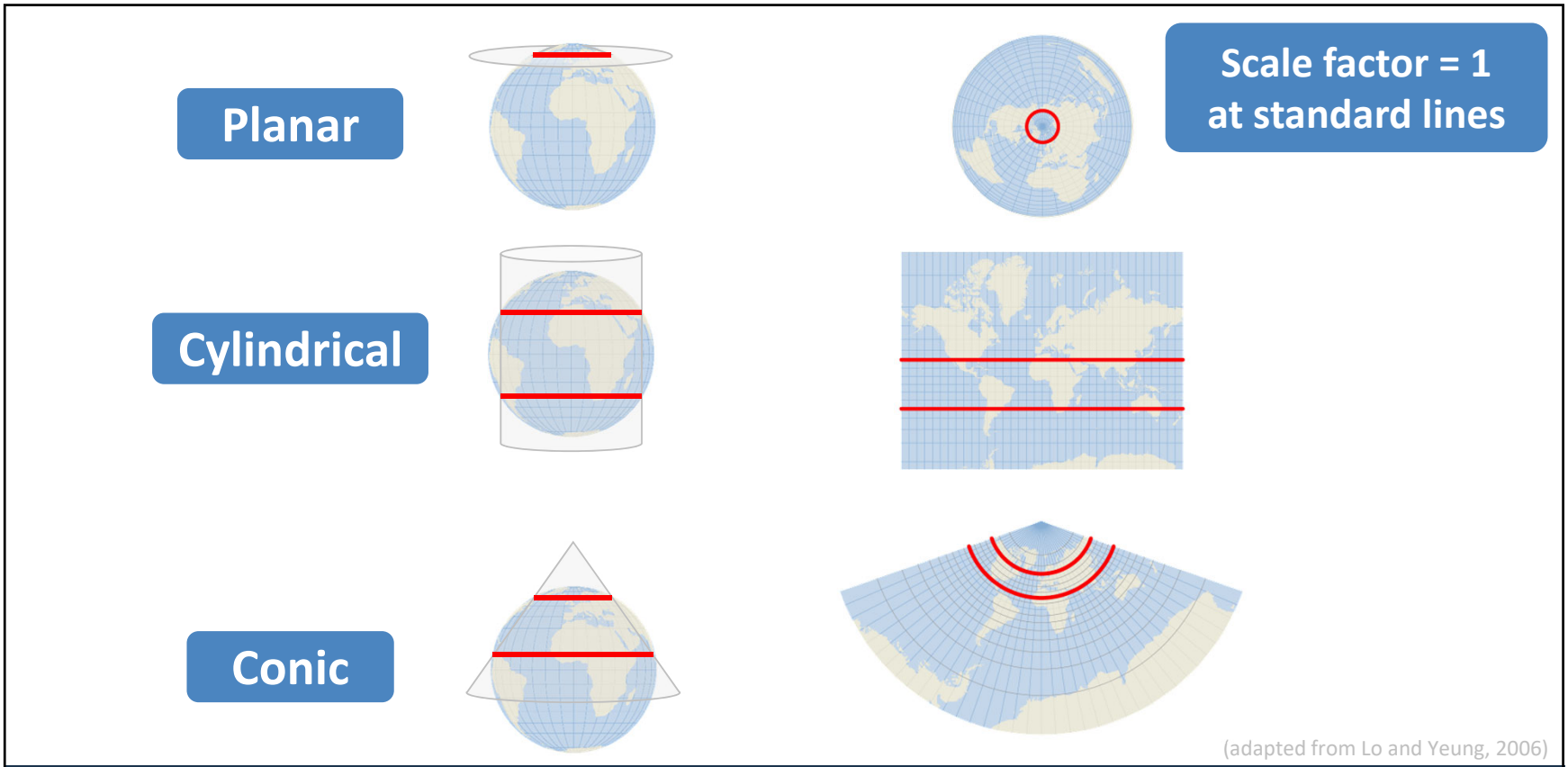




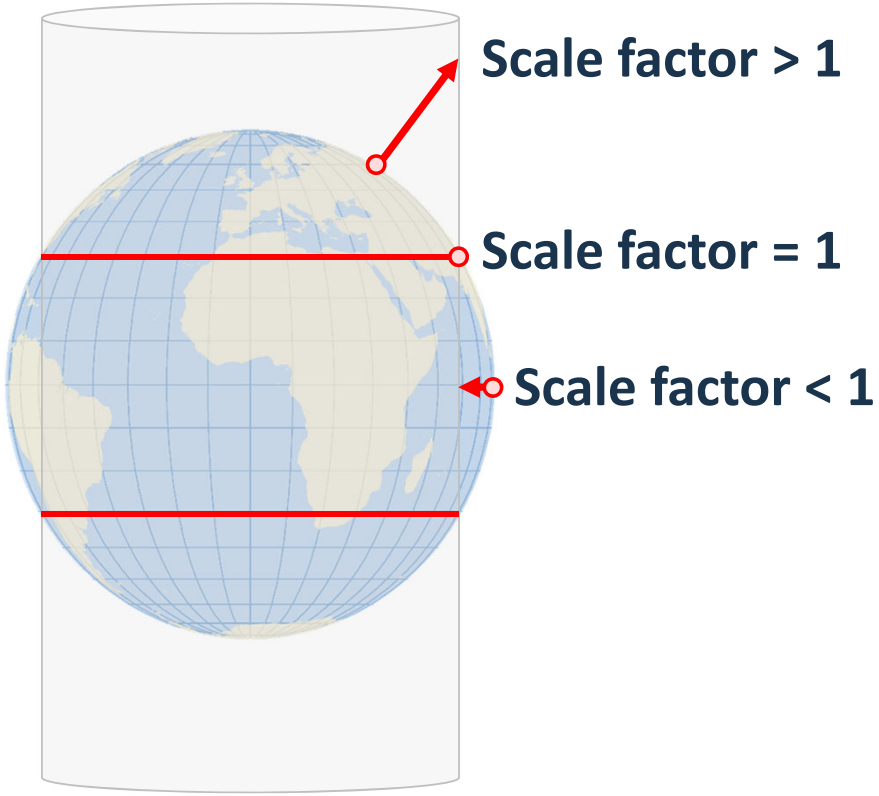
How can we reduce distortion?

(adapted from Lo and Yeung, 2006)

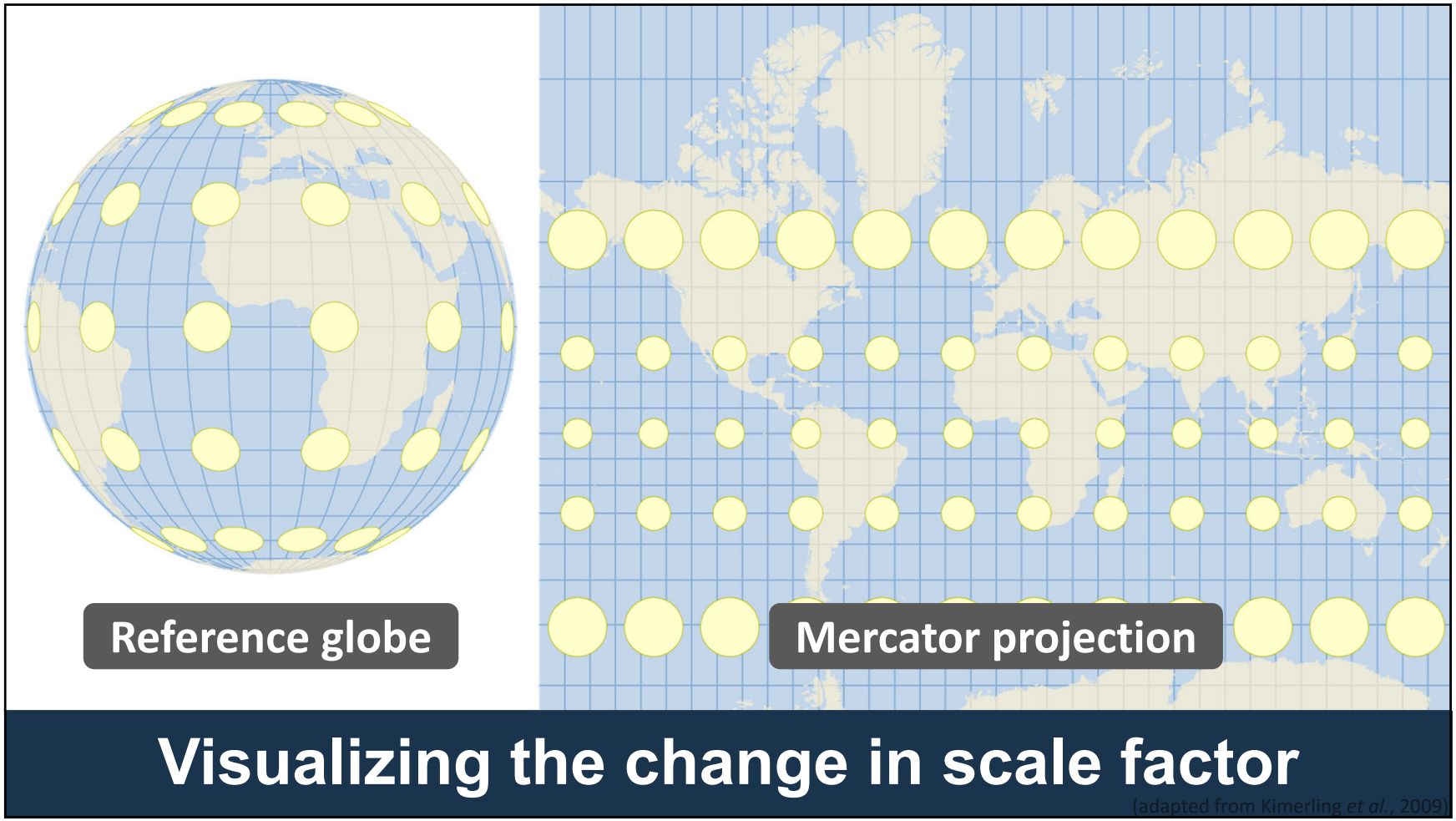
Tangent case



Secant case

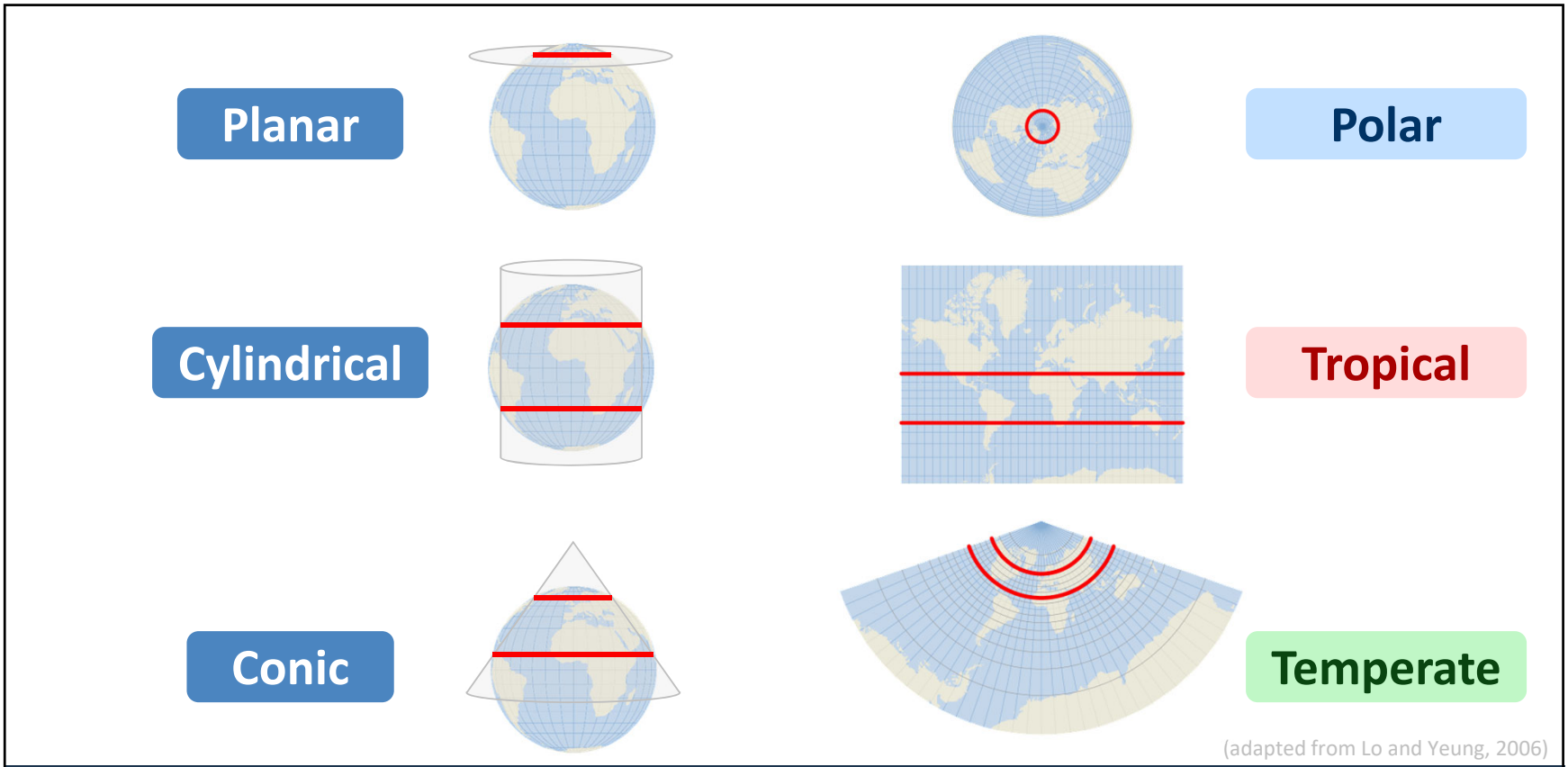


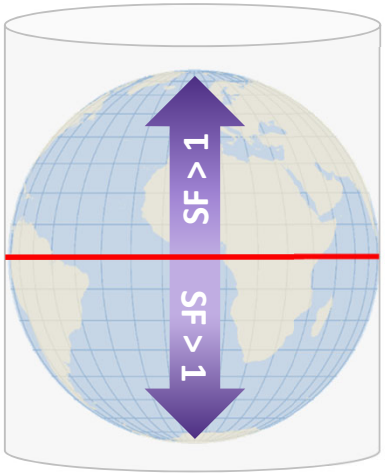
Scale factor with two standard lines



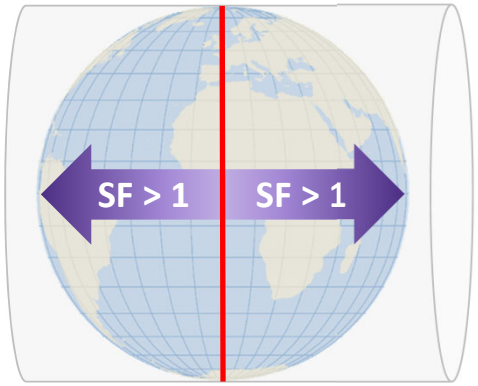
Visualizing the change in scale factor

(adapted from Kimerling *et al.*, 2009)

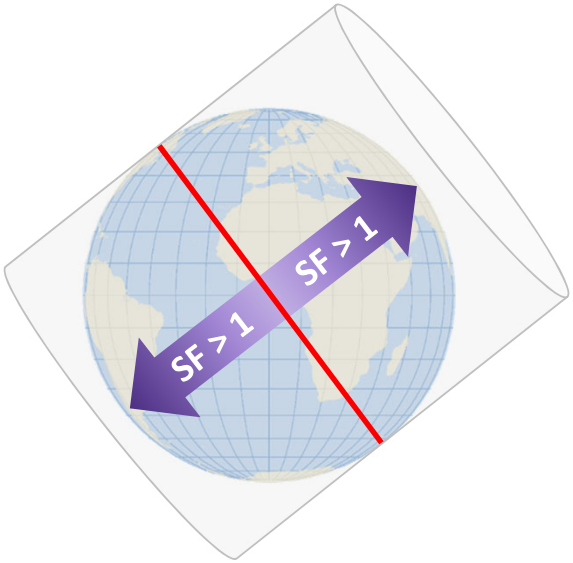




Normal



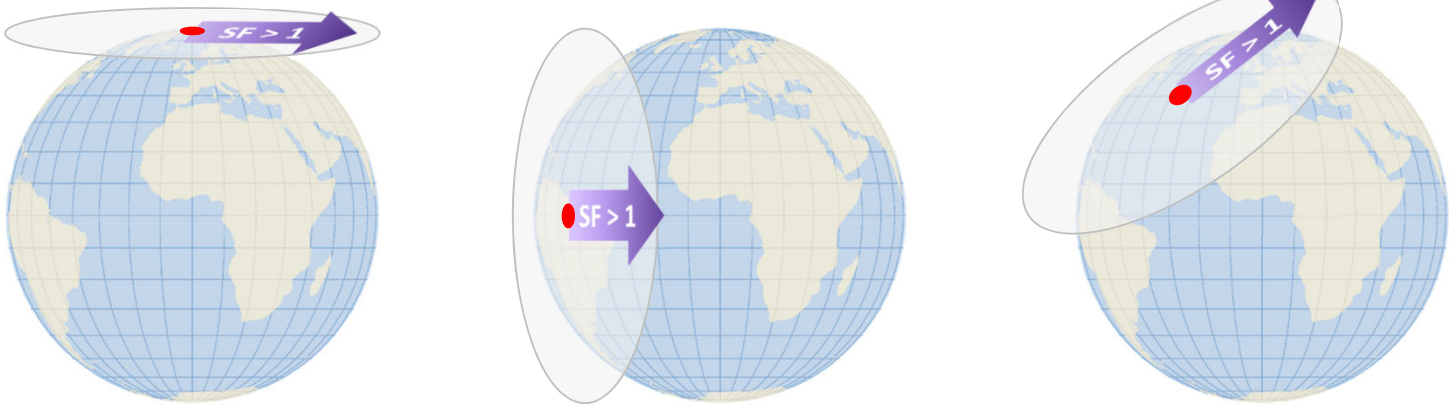
Transverse



Oblique

(adapted from Lo and Yeung, 2006)

Aspect

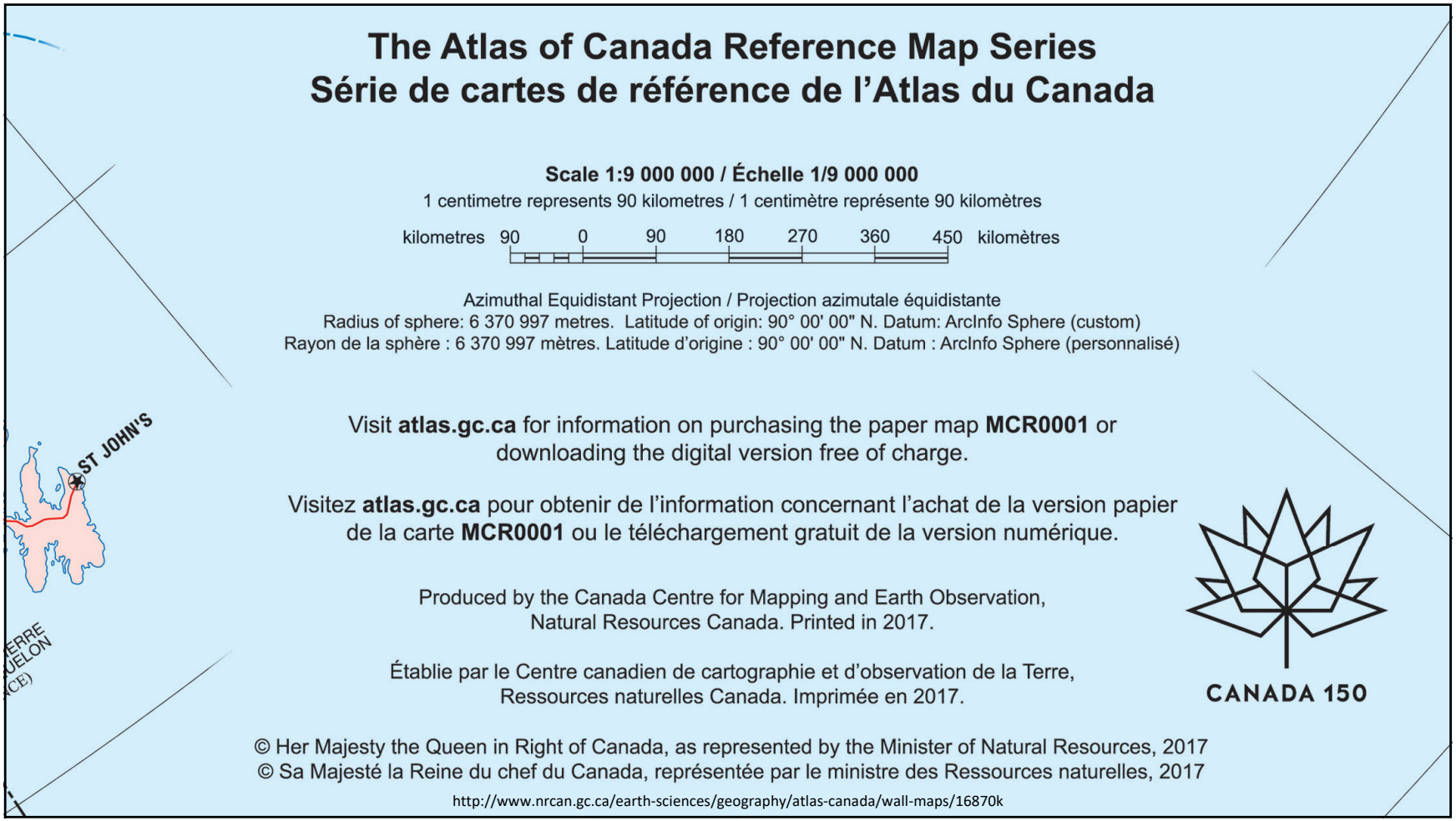


Polar **Equatorial** **Oblique**

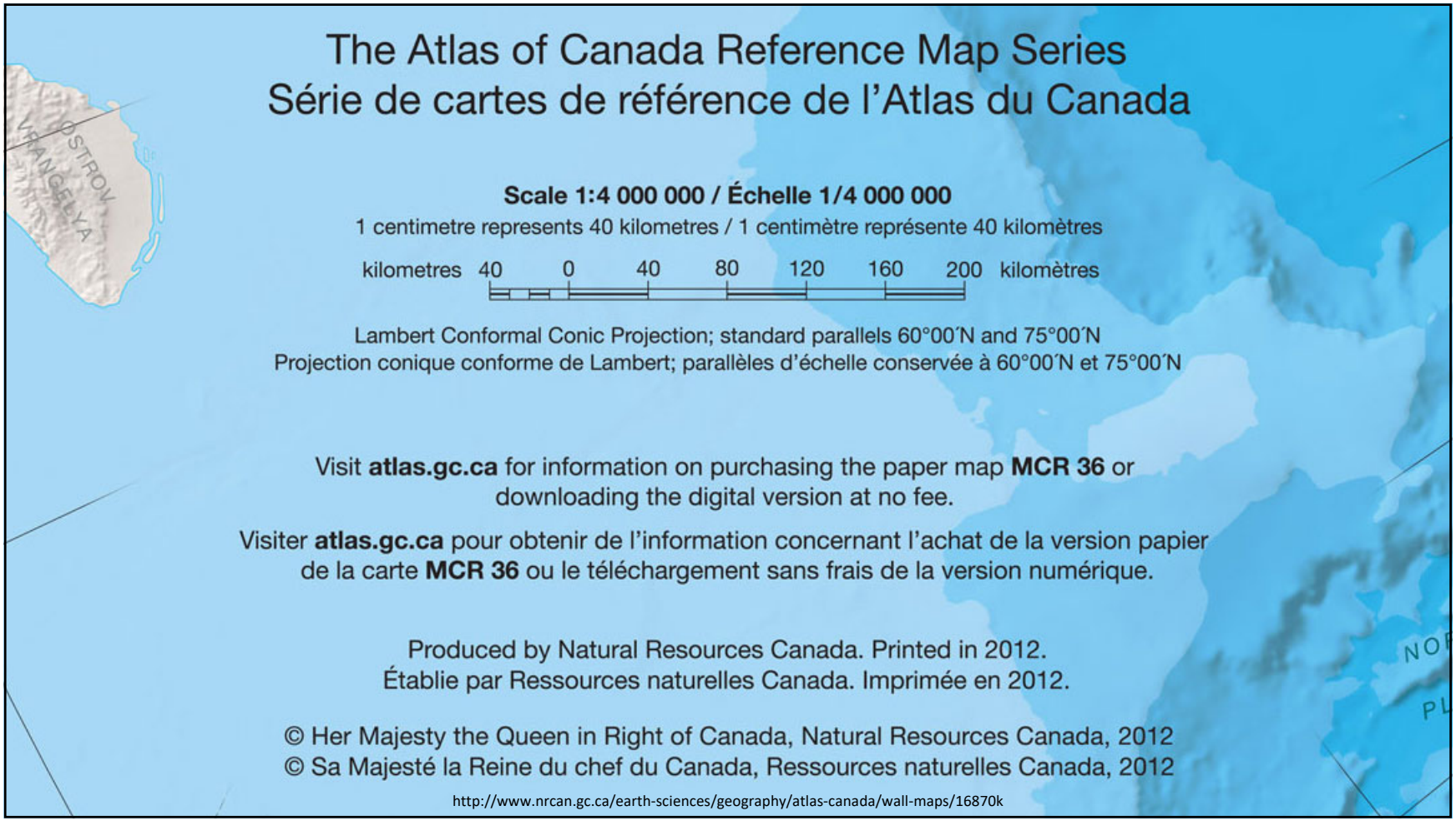
(adapted from Kimerling *et al.*, 2006)

Aspect

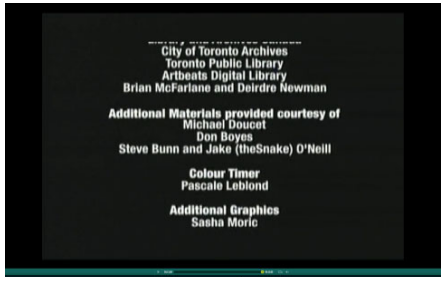
http://www.nrcan.gc.ca/earth-sciences/geography/atlas-canada/wall-maps/16870

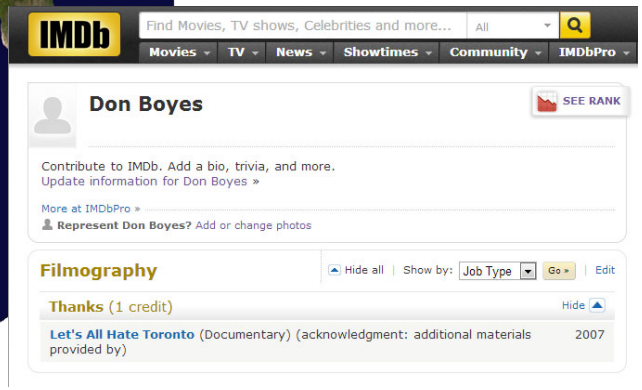


http://www.nrcan.gc.ca/earth-sciences/geography/atlas-canada/wall-maps/16870

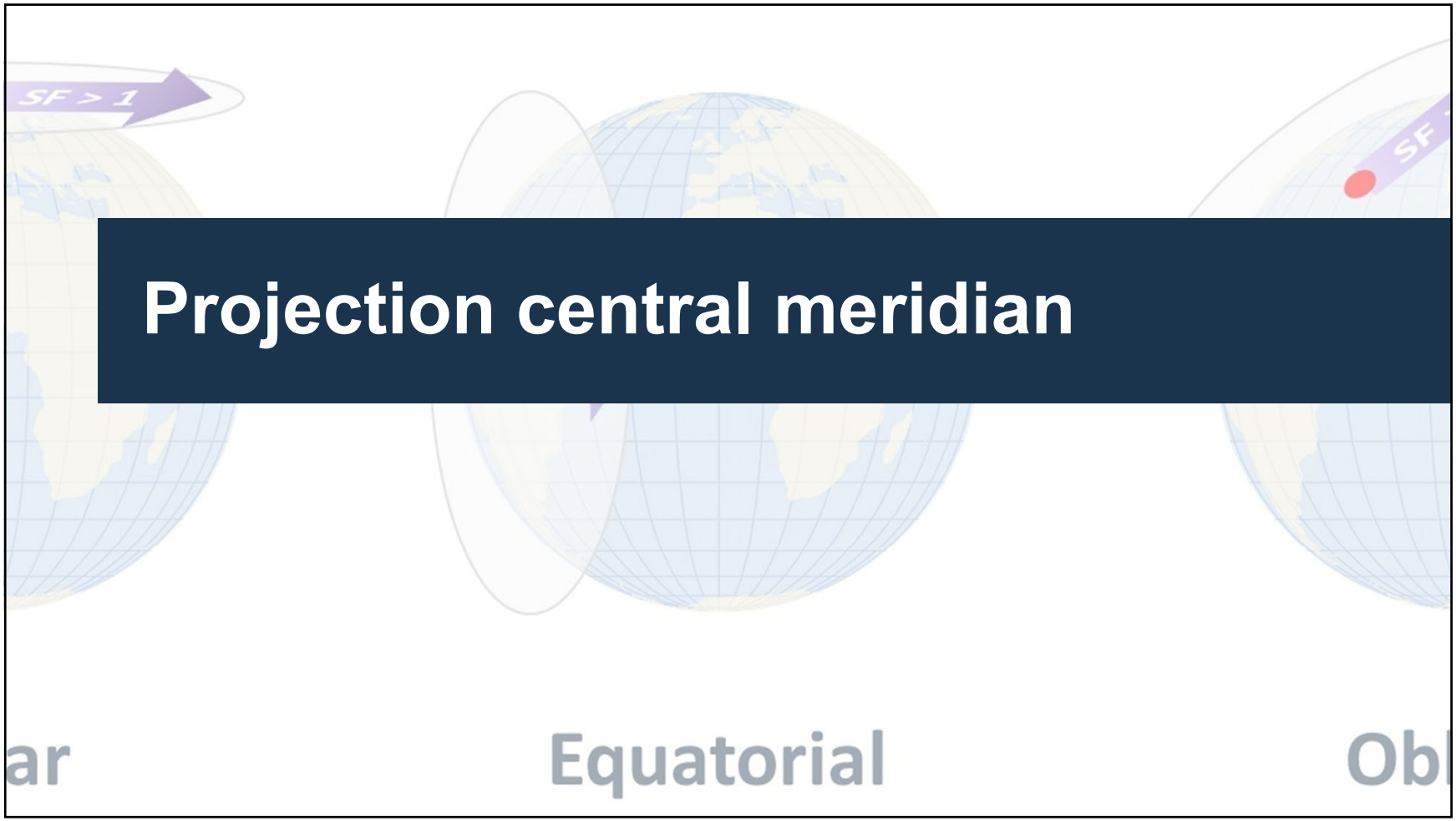


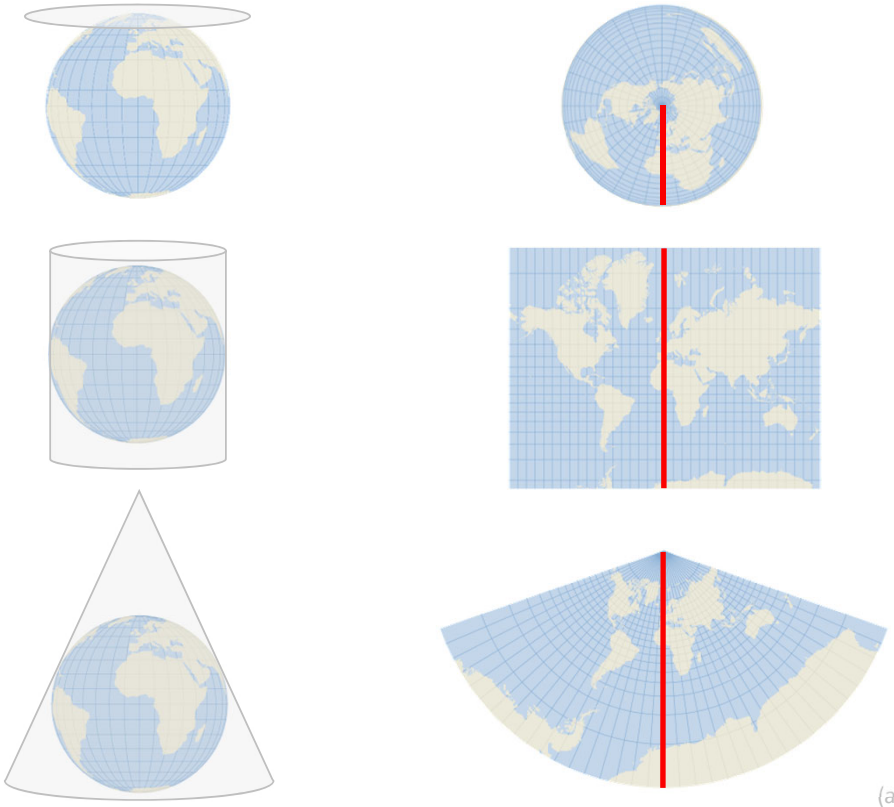
Eyeborg Rob Spence Eyeborg
@donboyes fun running into the mapman the other night!
41 minutes ago





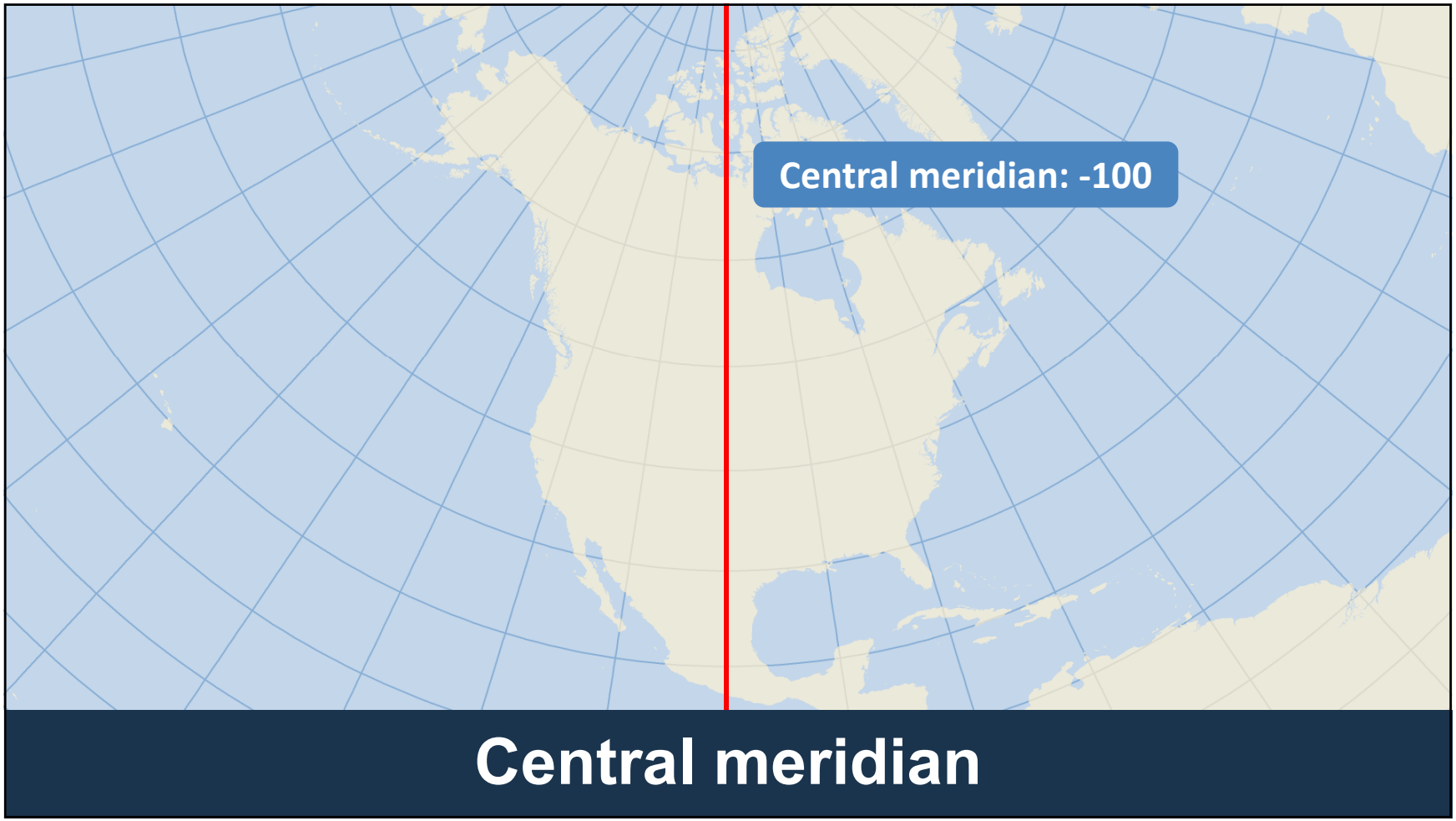
Let's all hate Toronto

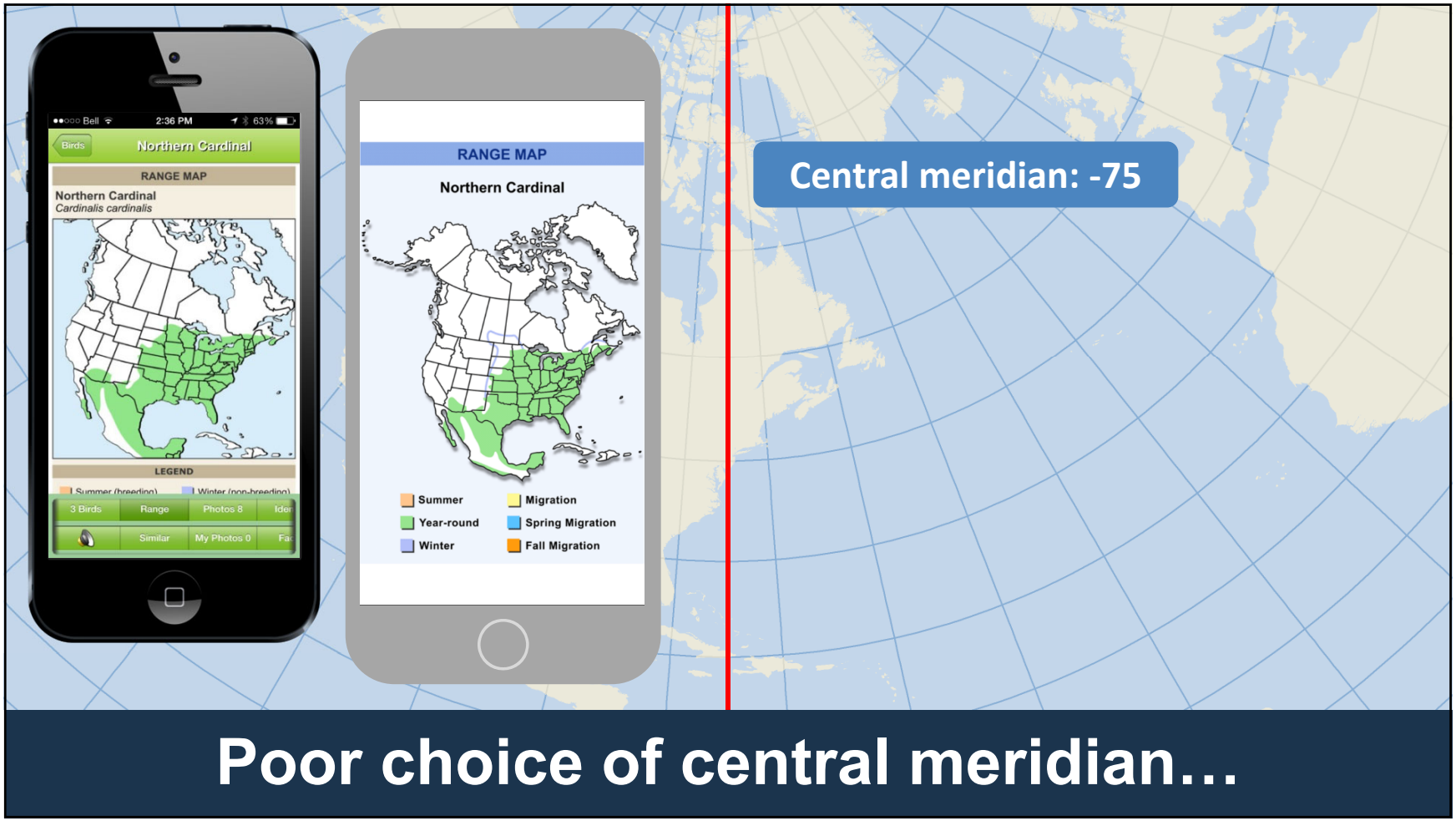




(adapted from Lo and Yeung, 2006)

Central meridian





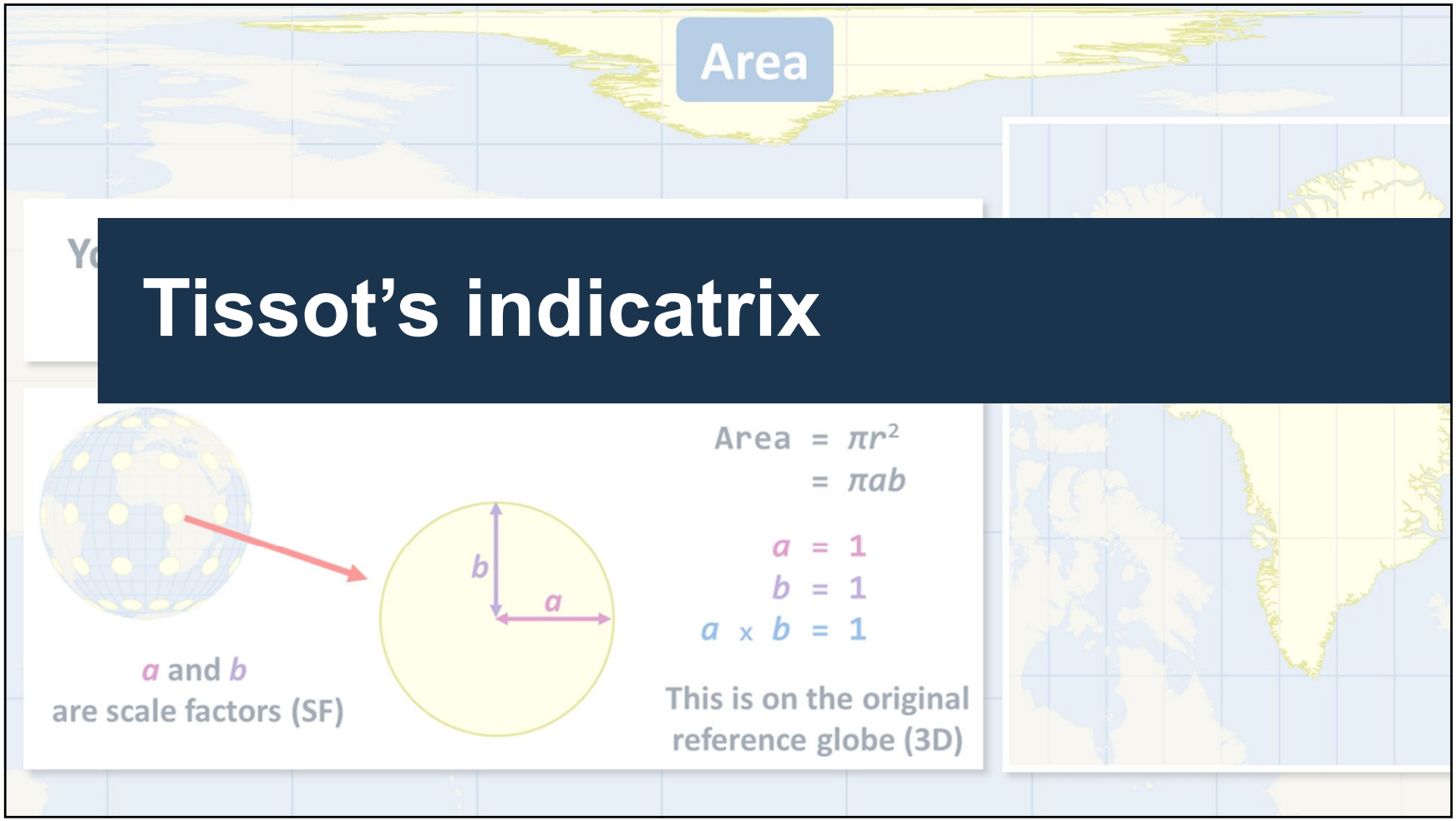
Poor choice of central meridian…

http://www.greenlandsc.com/en/World_America.aspx

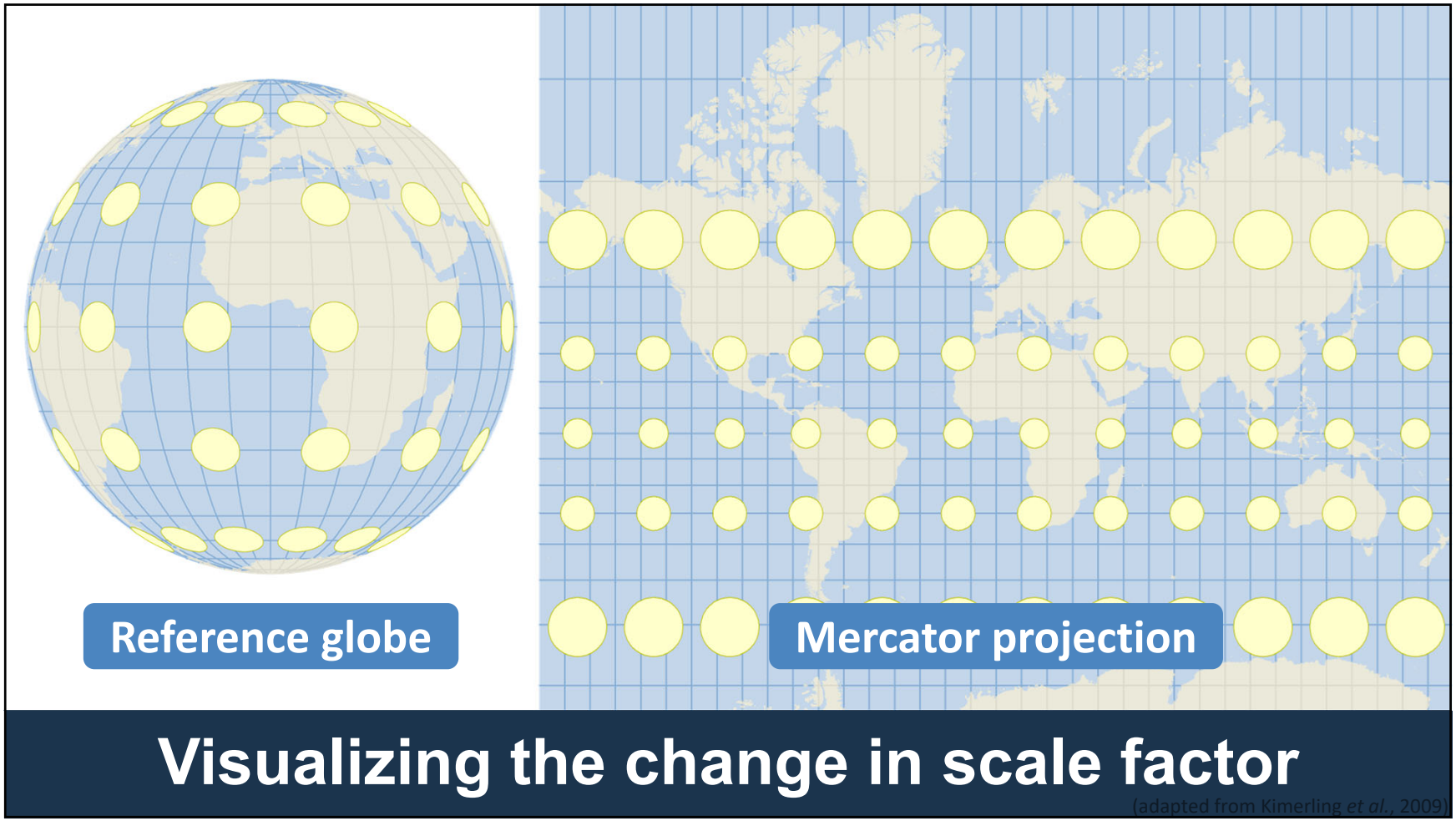
Poor choice of central meridian…

Central meridian set to China

Tissot's indicatrix



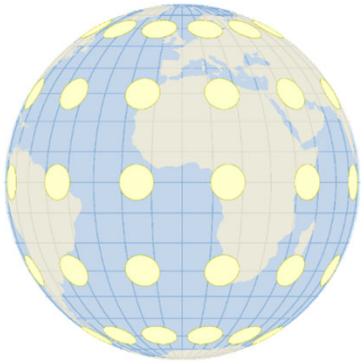
Observing distortion

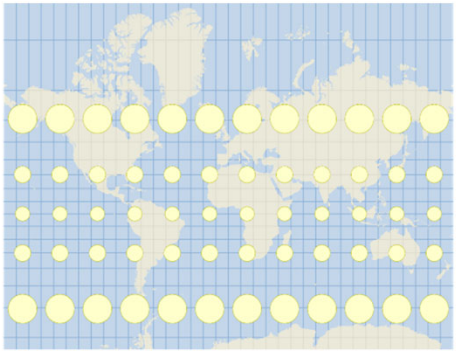


Visualizing the change in scale factor

(adapted from Kimerling *et al.*, 2009)

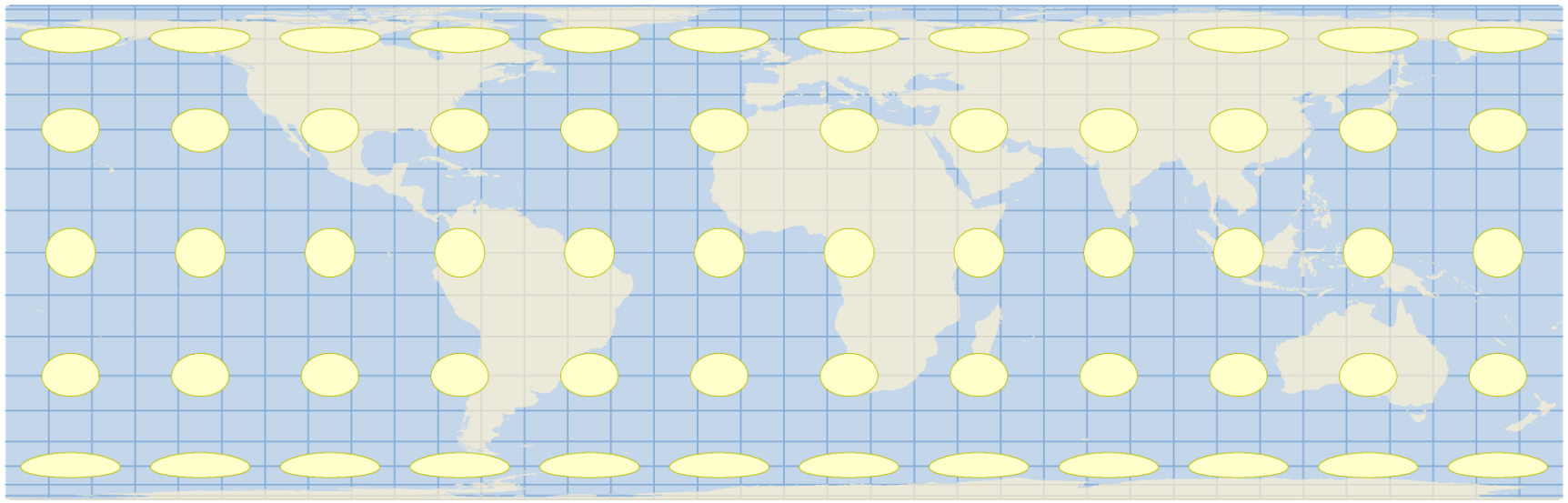
Tissot's Indicatrix



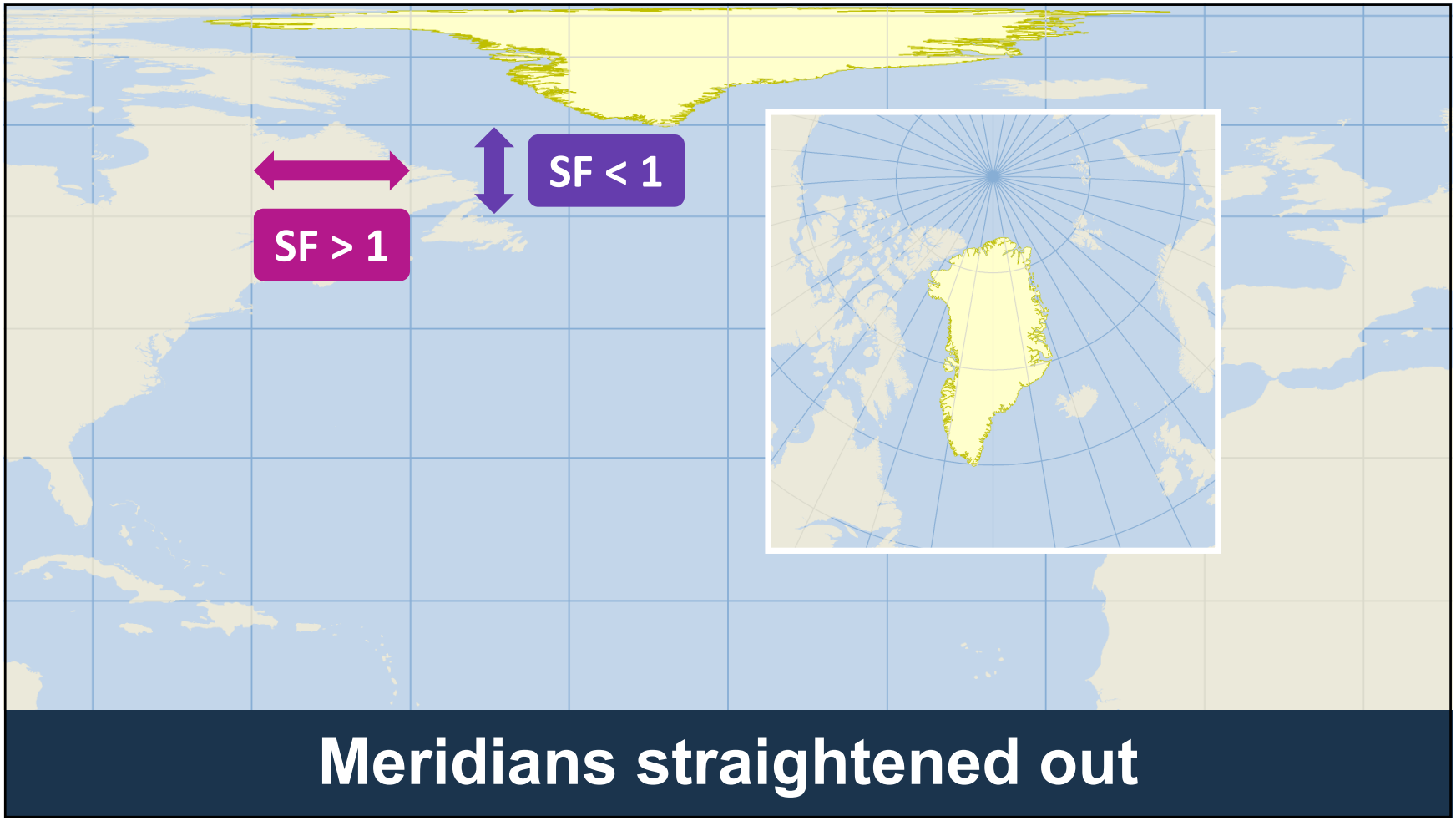


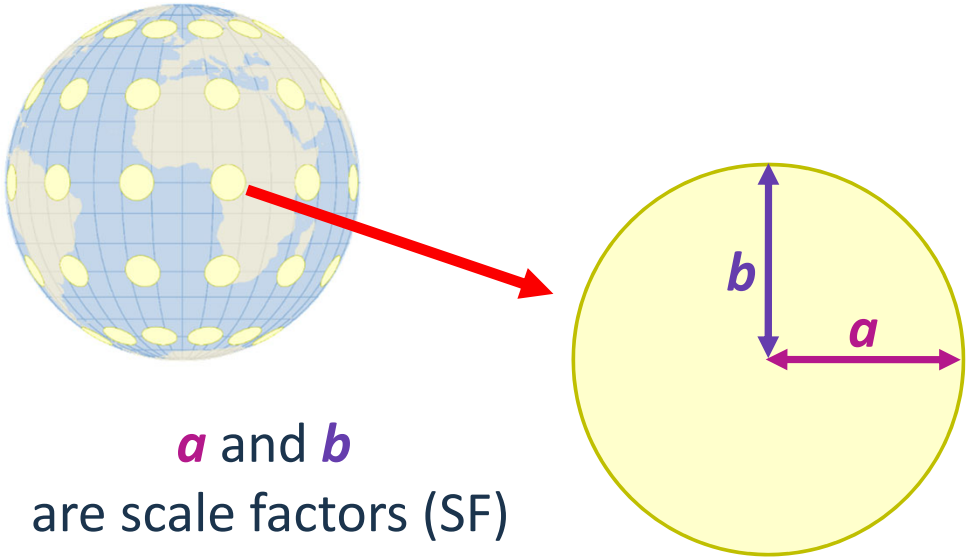
- Draw infinitely small circles on reference globe
- On globe, they are circles

- When projected, they are distorted in shape and/or size



Tissot's Indicatrix: Cylindrical Equal Area





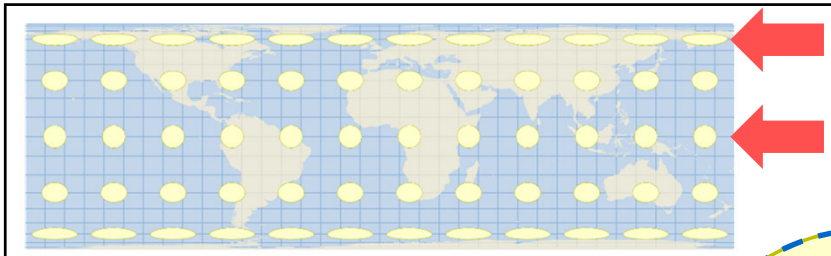
a and ***b***
are scale factors (SF)

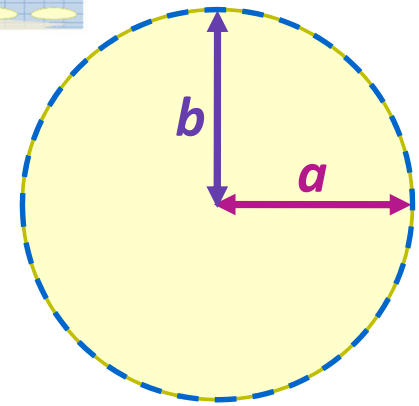
$$\text{Area} = \pi r^2$$
$$= \pi ab$$

$$a = 1$$
$$b = 1$$
$$a \times b = 1$$

This is on the **original reference globe (3D)**

Tissot's Indicatrix



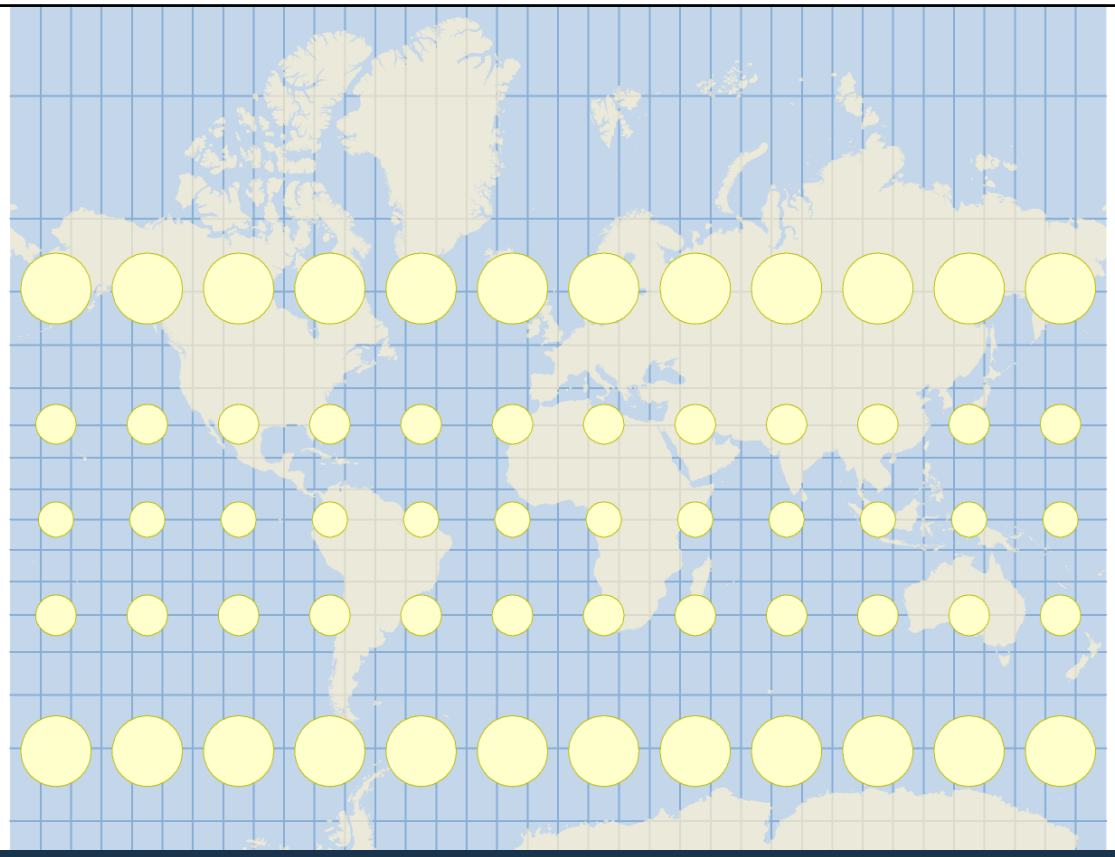


$$\text{Area} = \pi r^2$$
$$= \pi a b$$

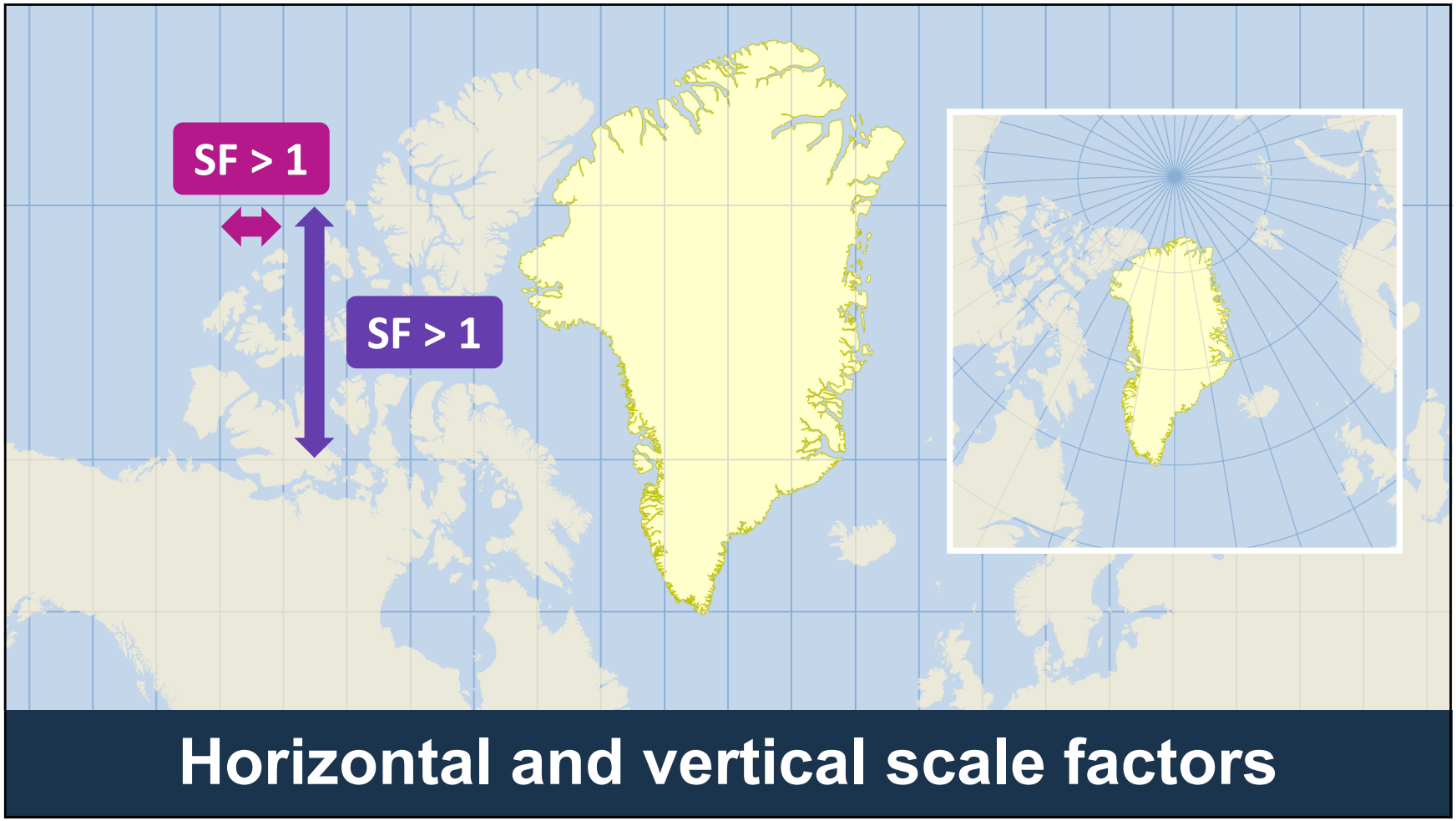
$$a = 1.25$$
$$b = 0.8$$
$$a \times b = 1$$

Since a x b = 1,
2D map is **equal-area**
but $a \neq b$
so map is **not conformal**

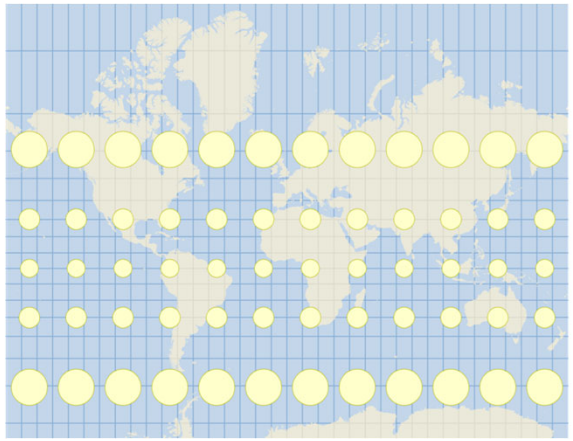
Shapes distorted

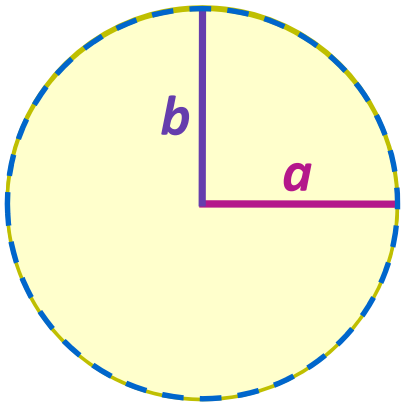


Tissot's Indicatrix: Mercator



Horizontal and vertical scale factors



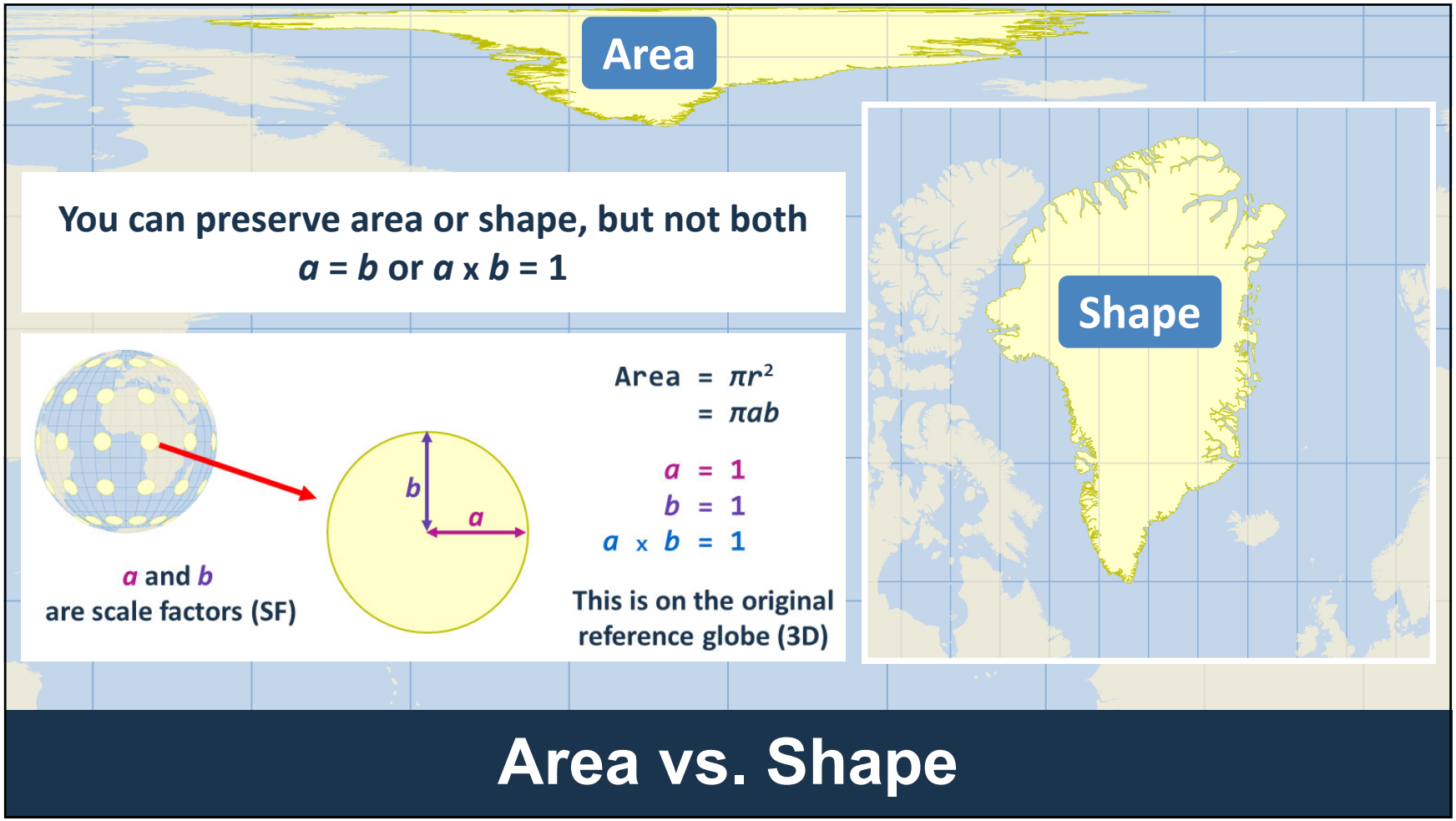


$$\text{Area} = \pi r^2$$
$$= \pi a b$$

$$a = 1.25$$
$$b = 1.25$$
$$a \times b = 1.5625$$

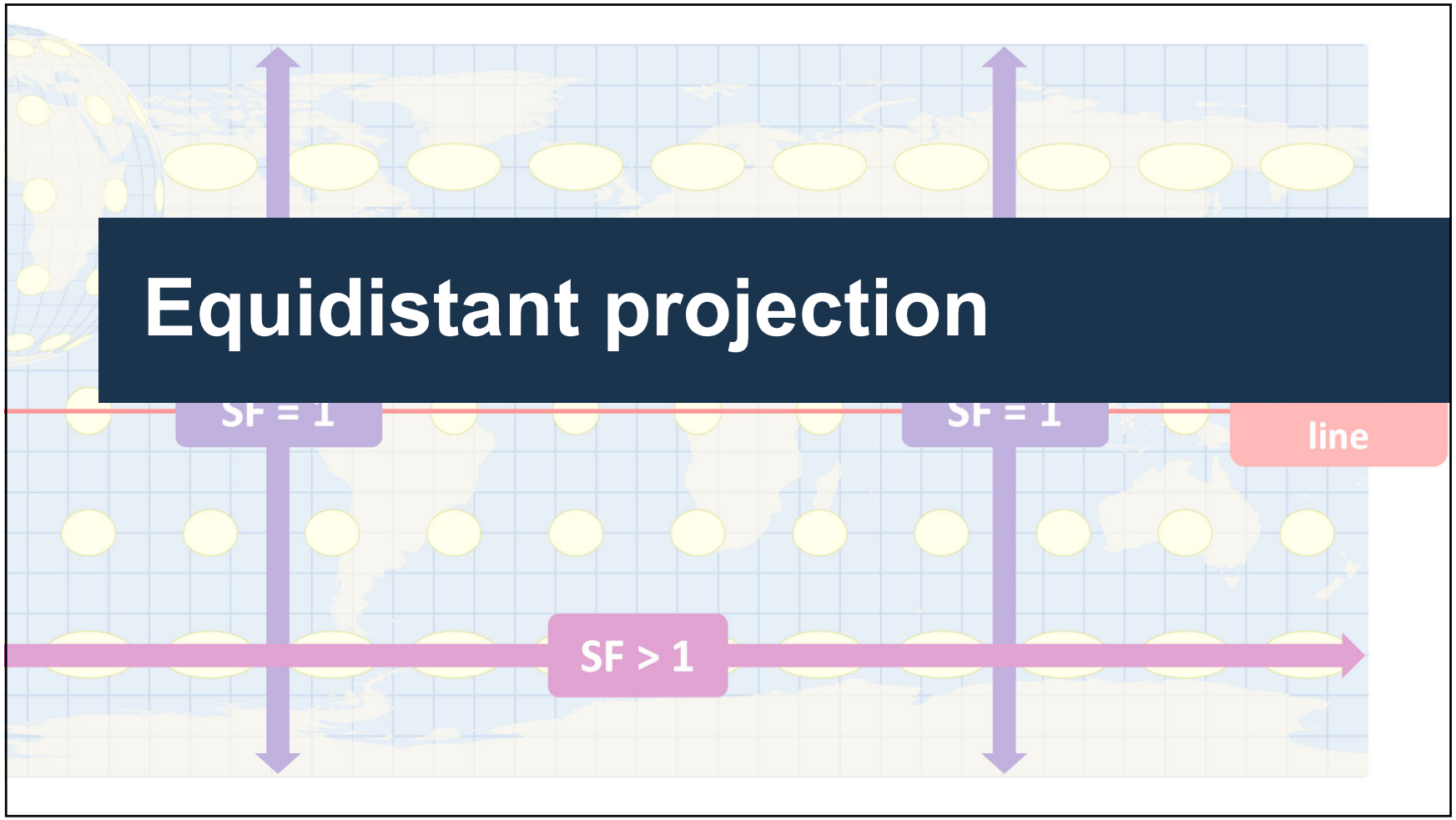
Since $a \times b \neq 1$,
2D map is **not equal-area**
but $a = b$
so map is **conformal**

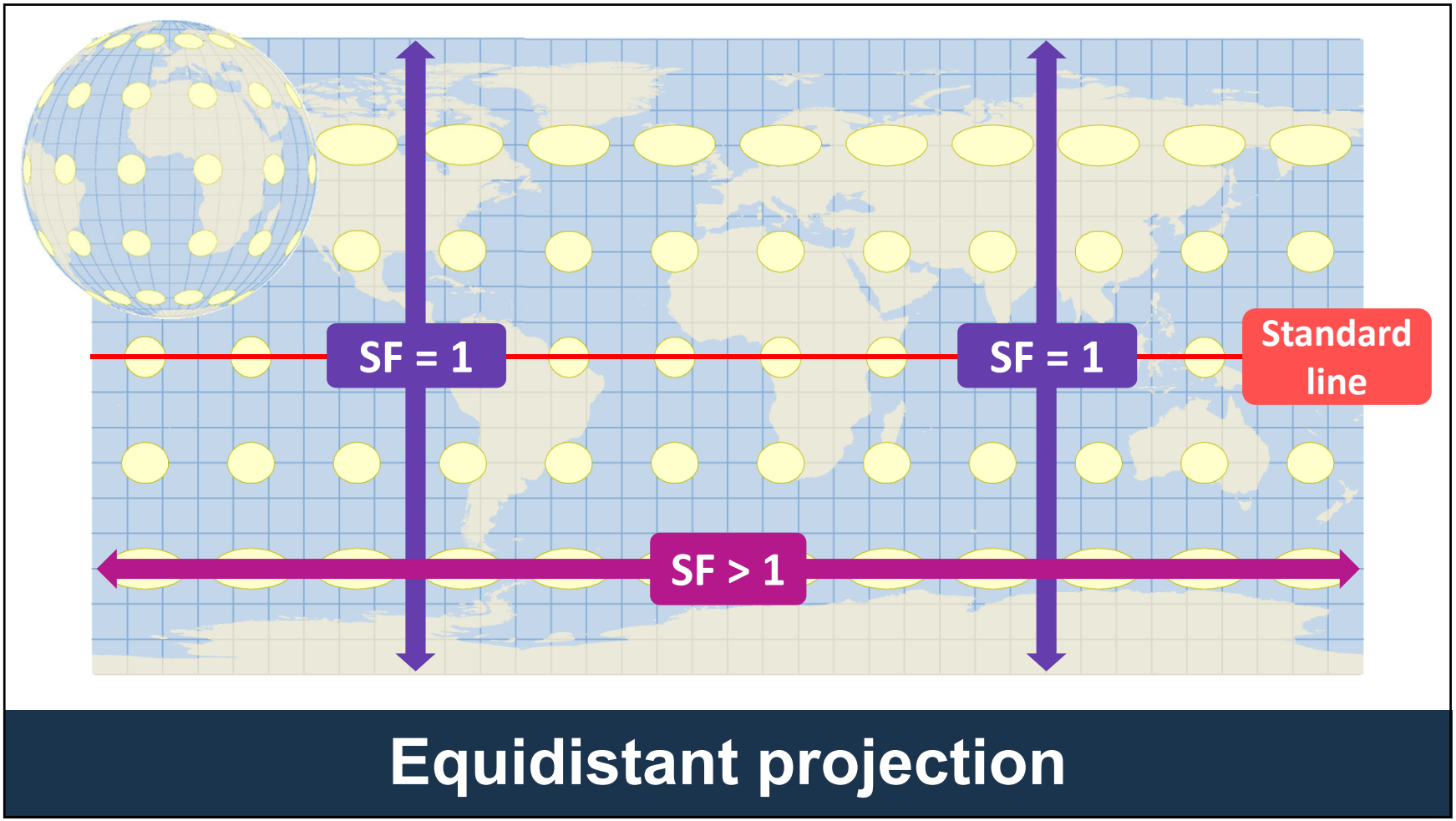
Sizes distorted



Area vs. Shape

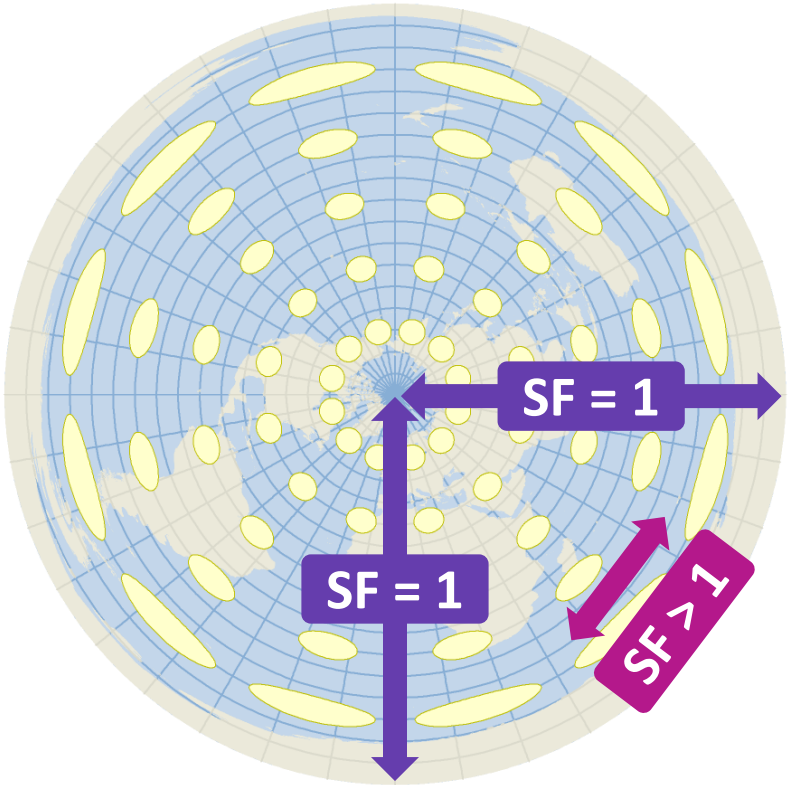
Equidistant projection



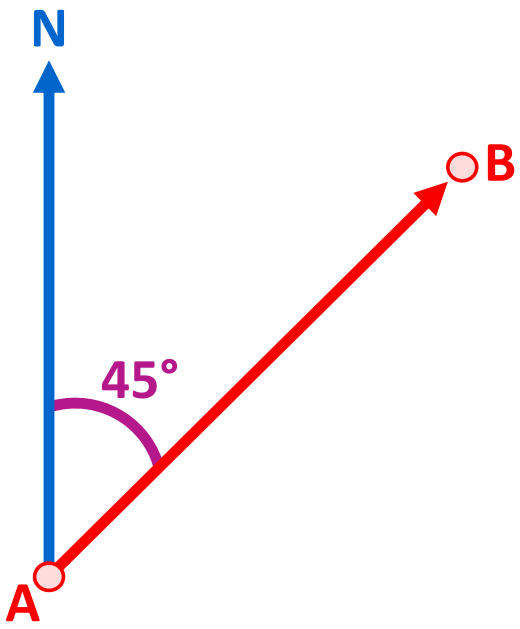


Equidistant projection

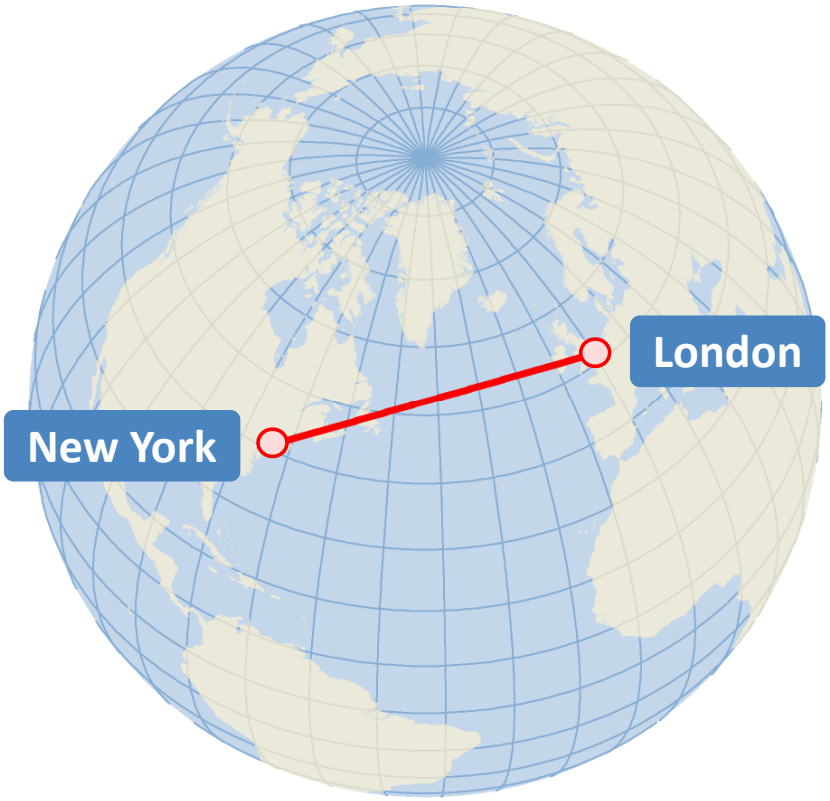
Great circles and rhumb lines



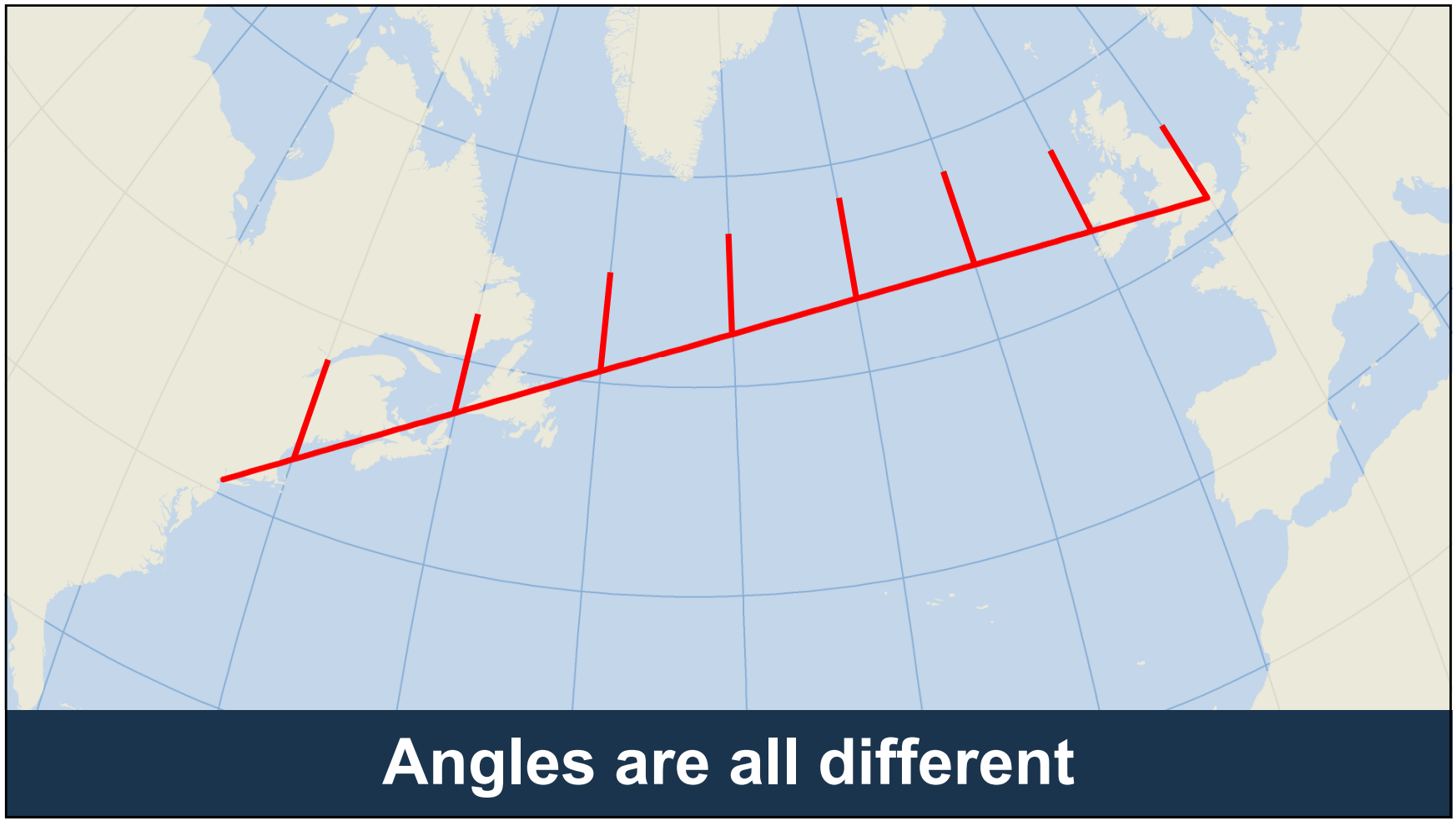
Equidistant projection

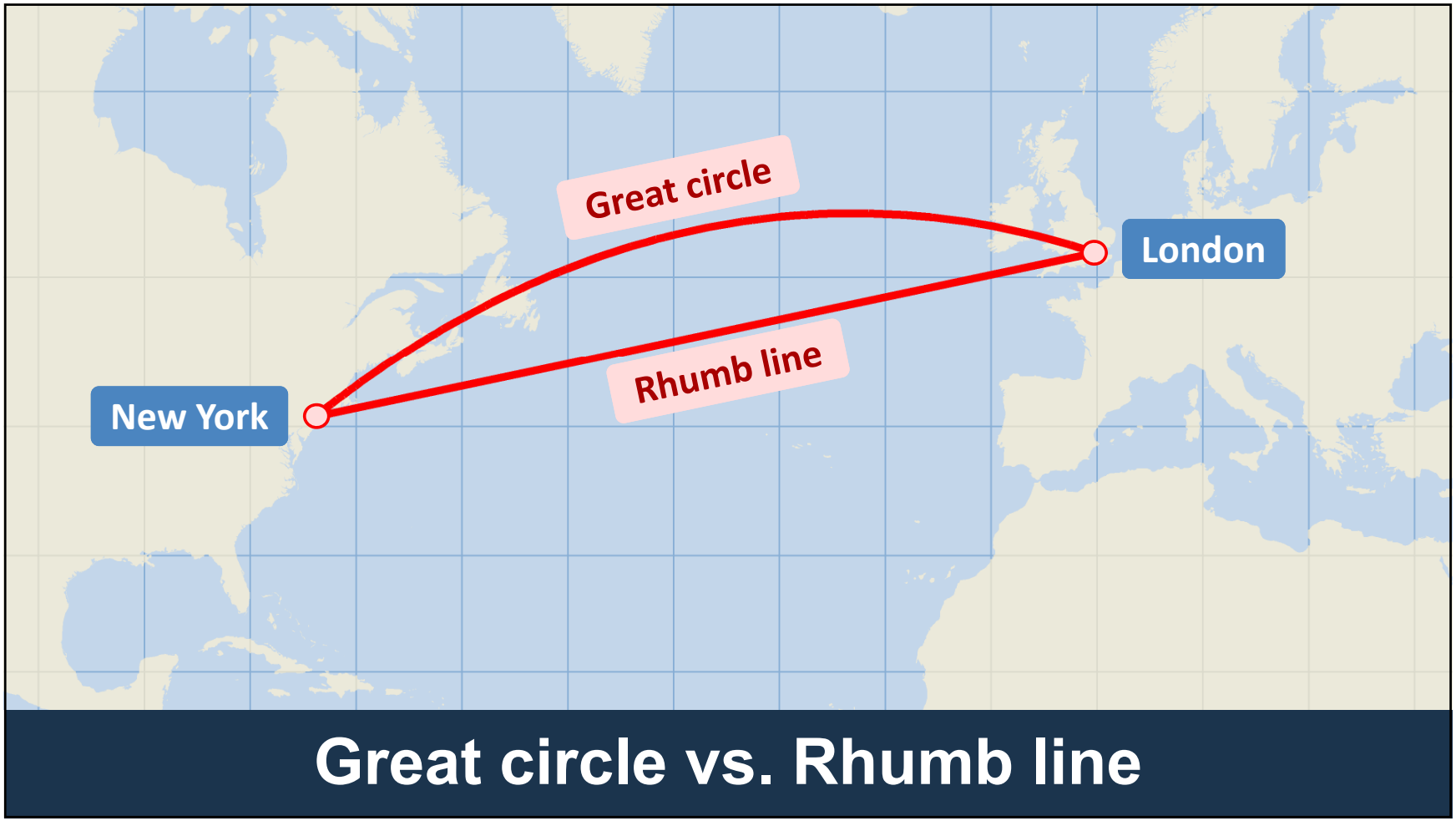


Azimuth

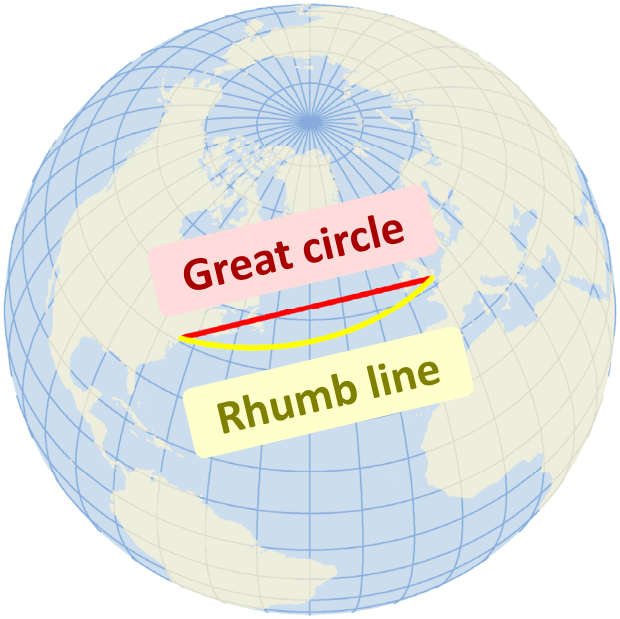


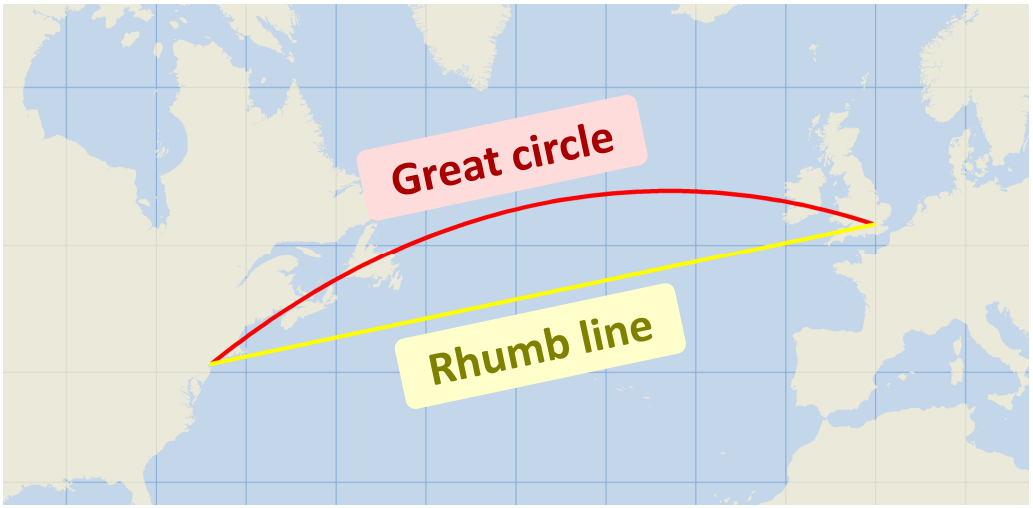
Great circle route



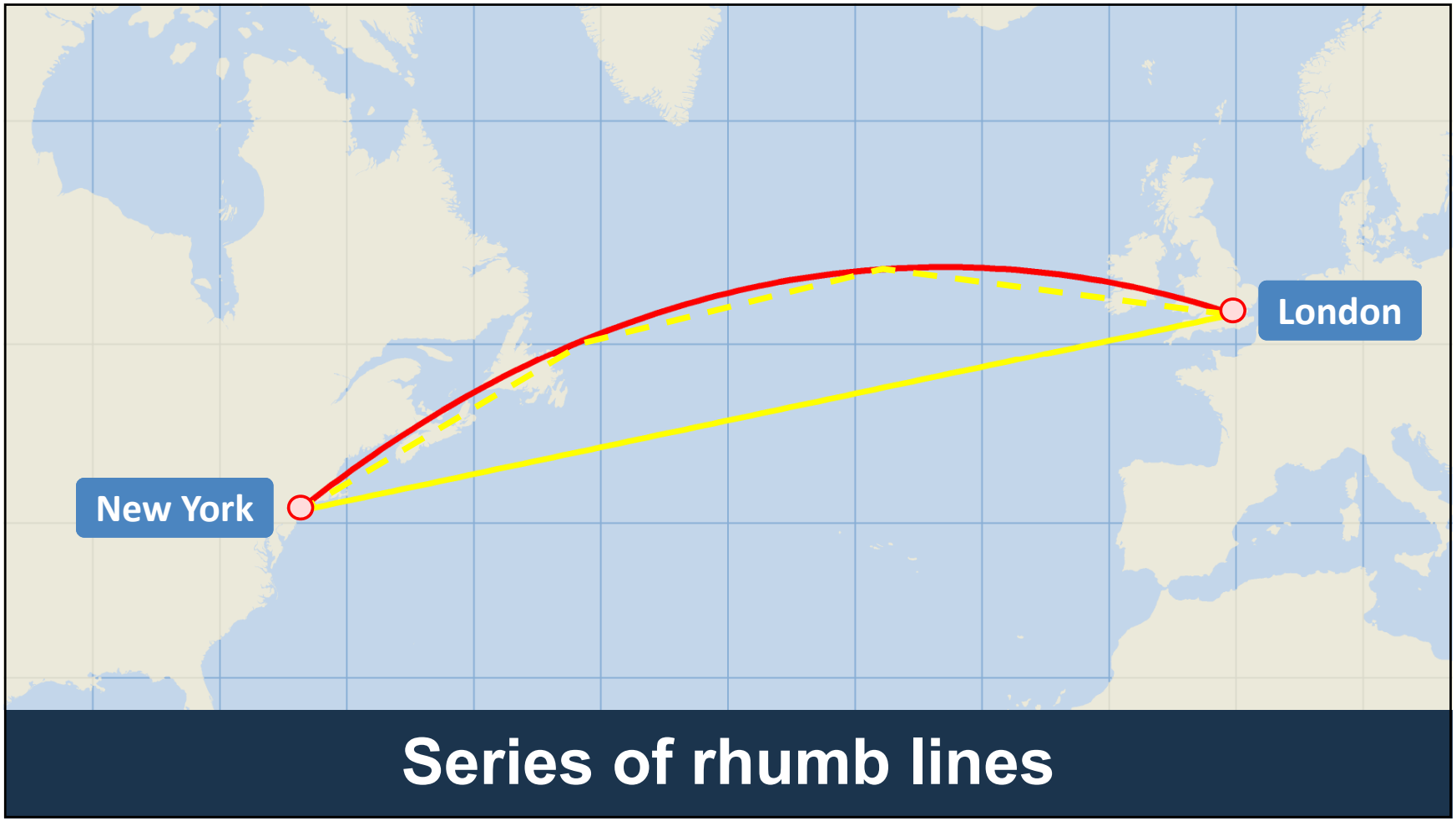


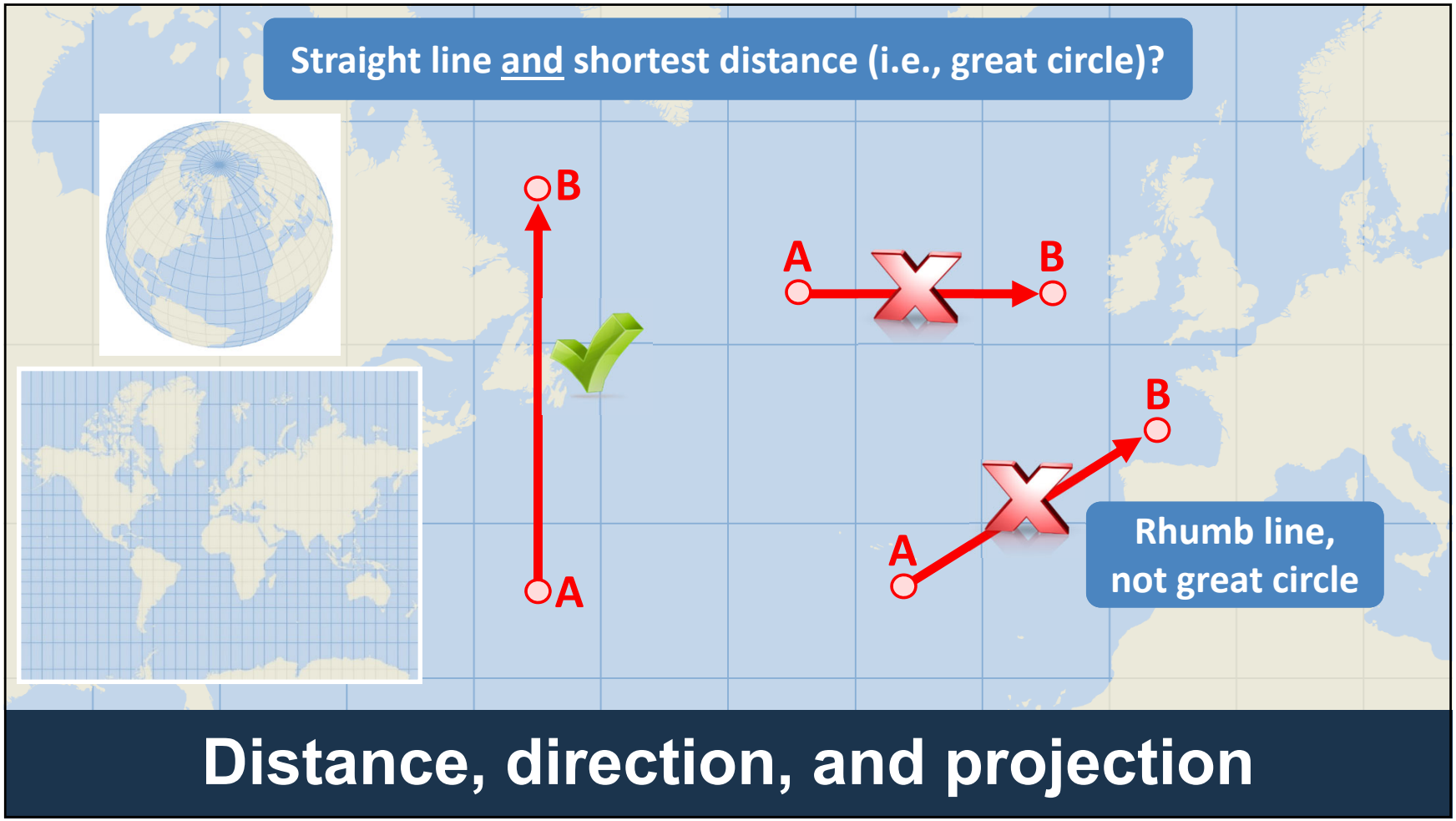
Great circle vs. Rhumb line



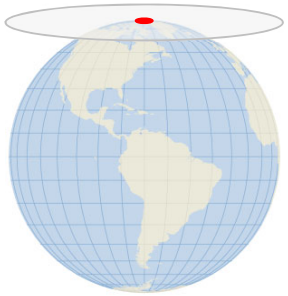


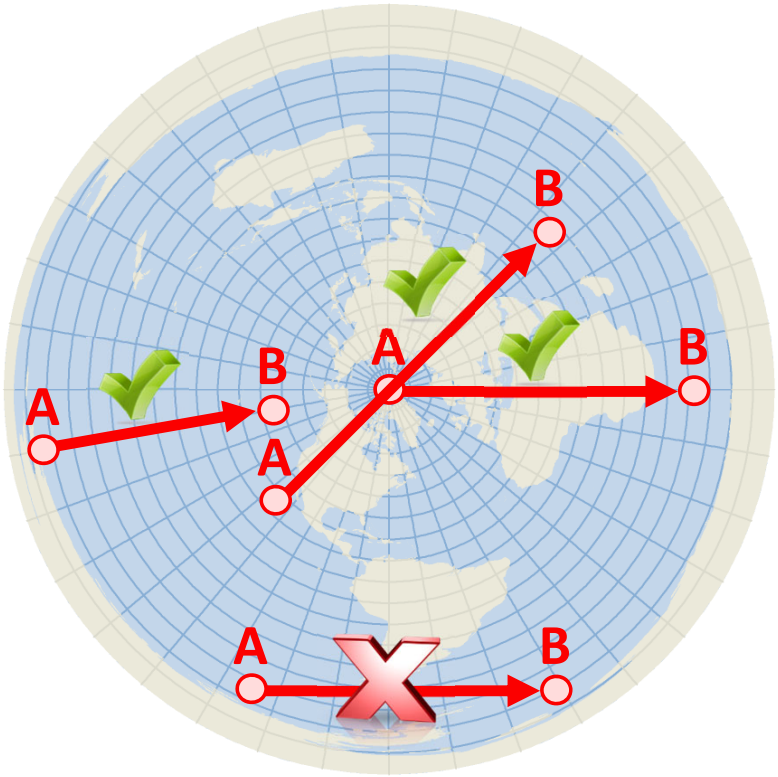
Rhumb lines are longer (really!)



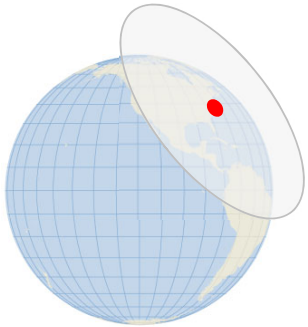


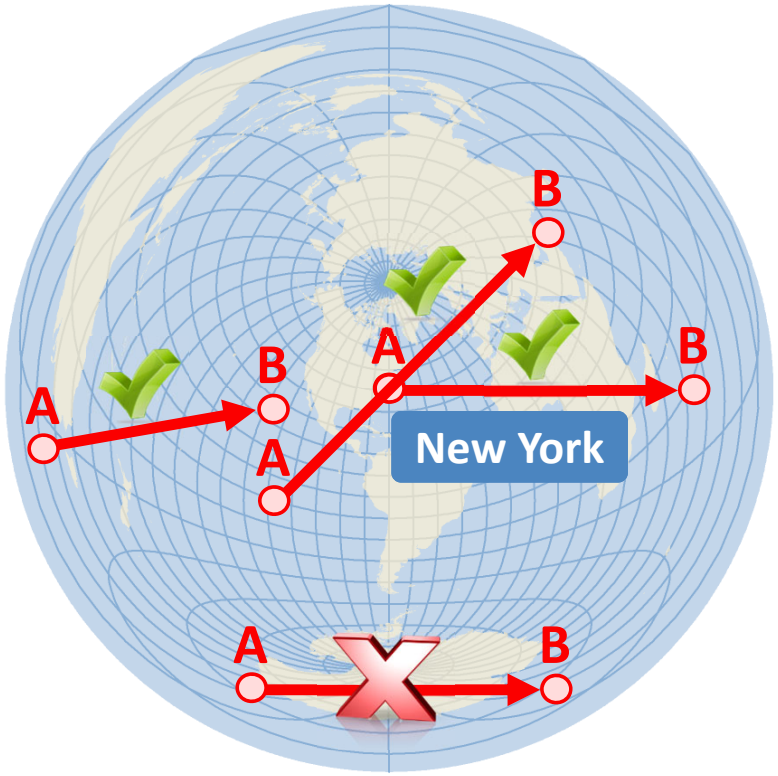
Distance, direction, and projection



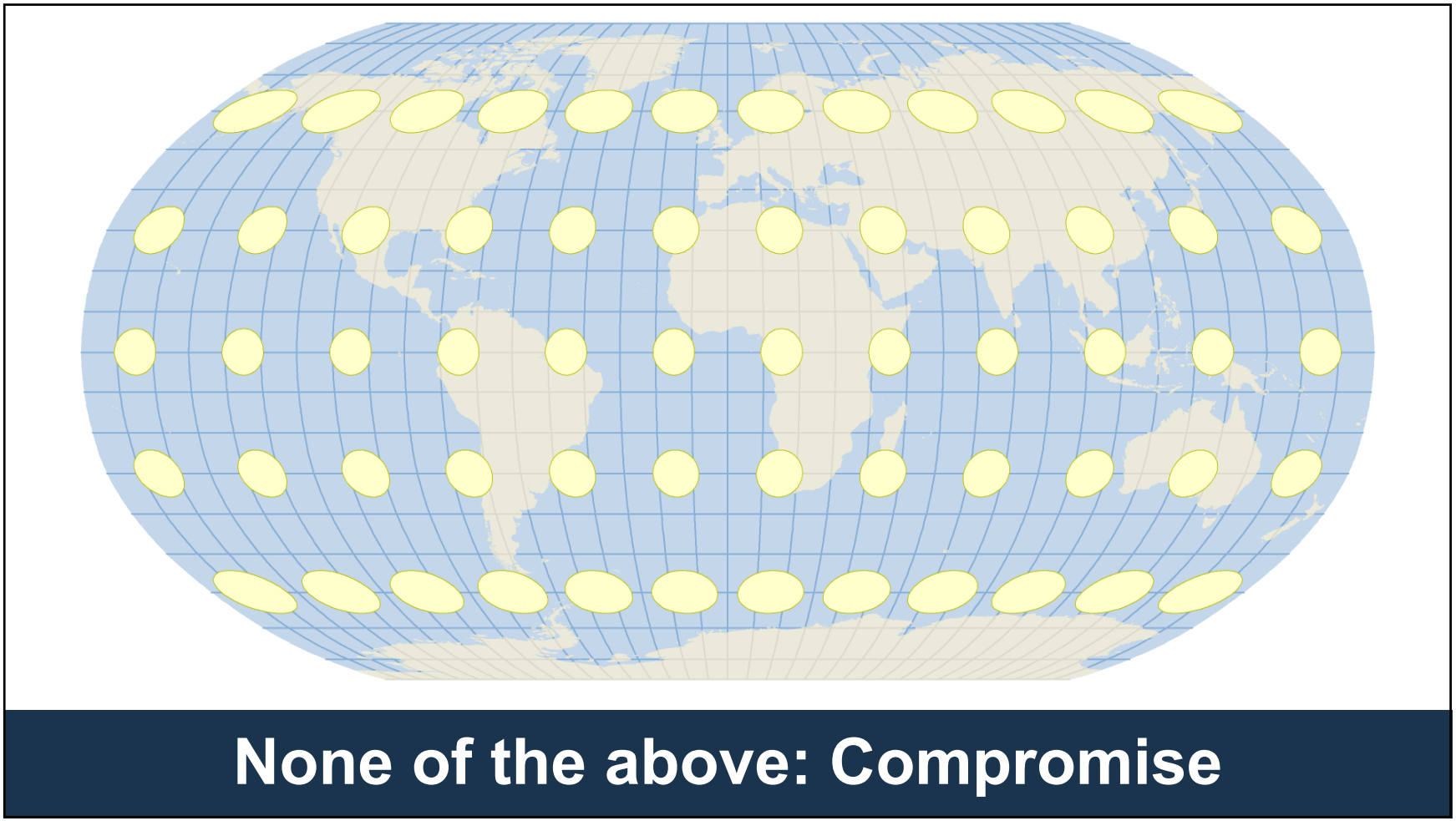


Direction and projection

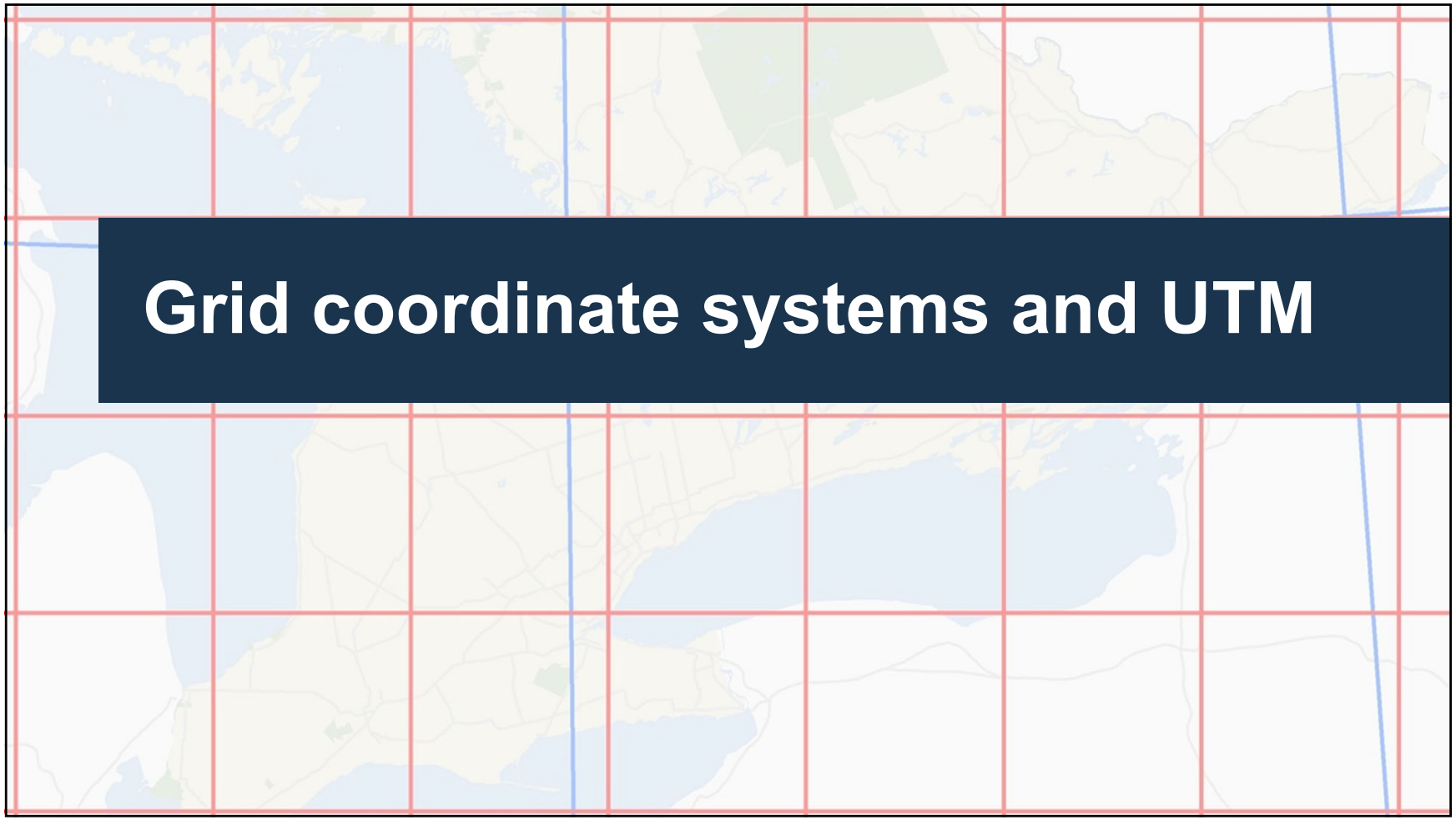




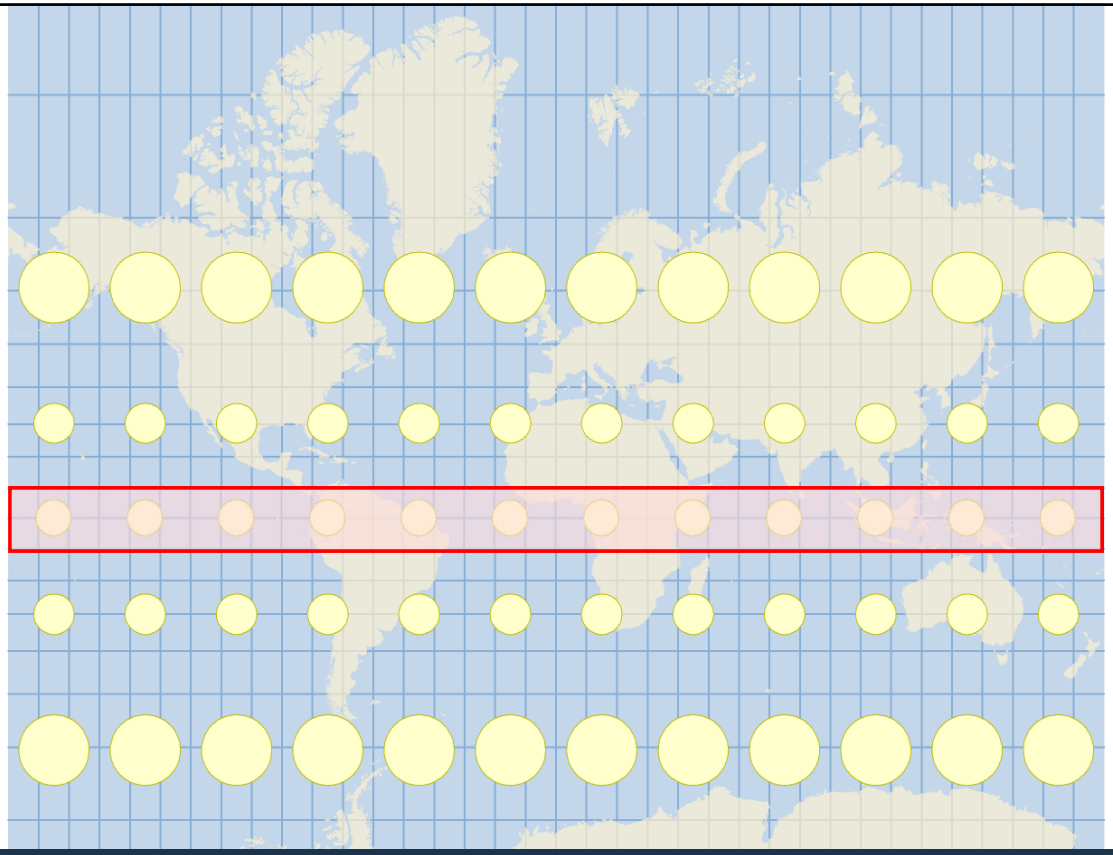
Azimuthal projection centered on New York



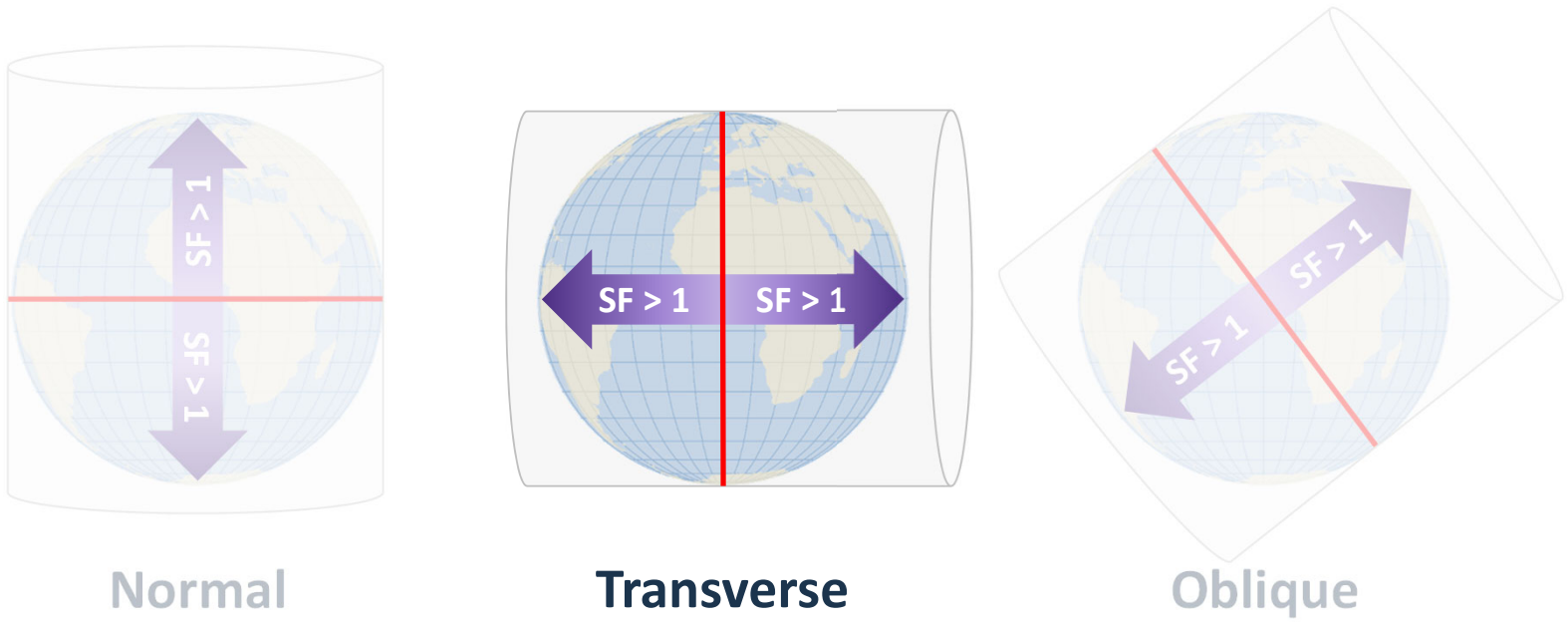
None of the above: Compromise



Grid coordinate systems and UTM

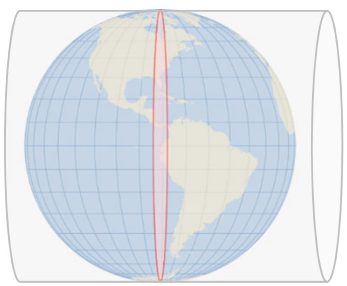


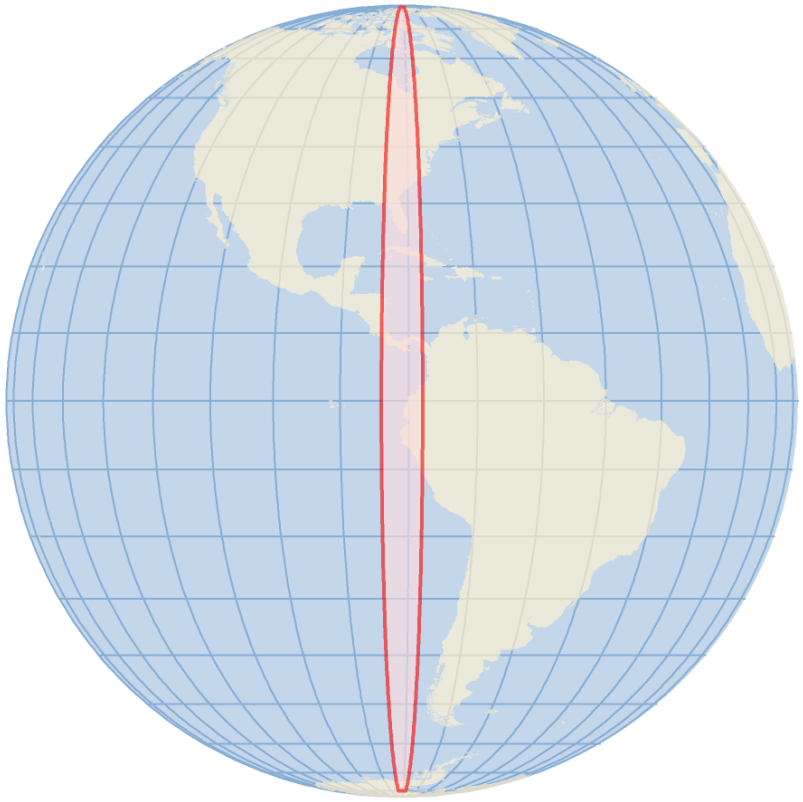
Mercator projection



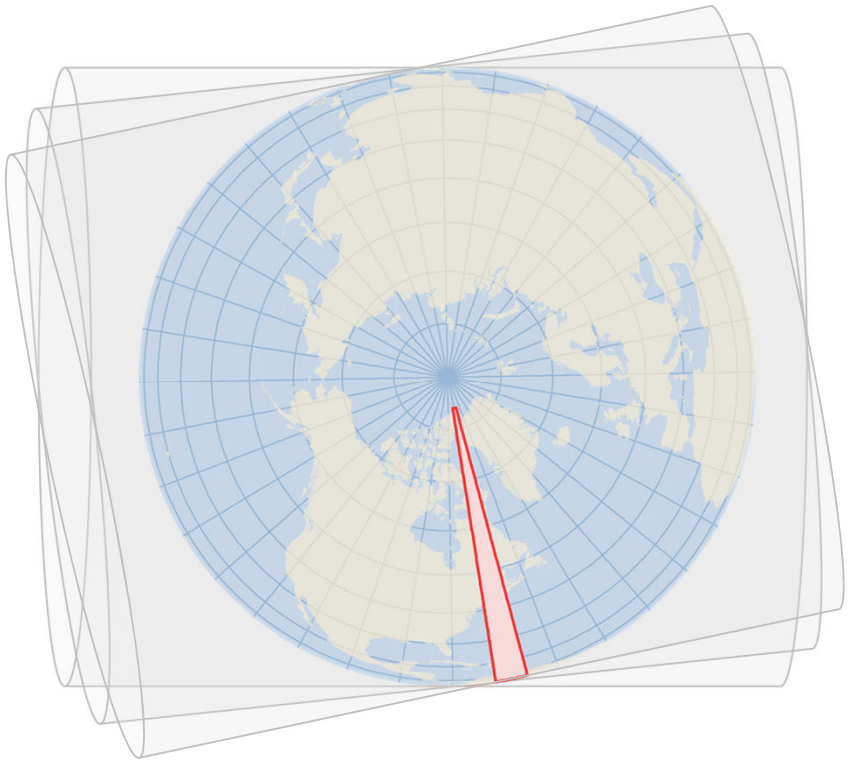
(adapted from Lo and Yeung, 2006)

Transverse Mercator



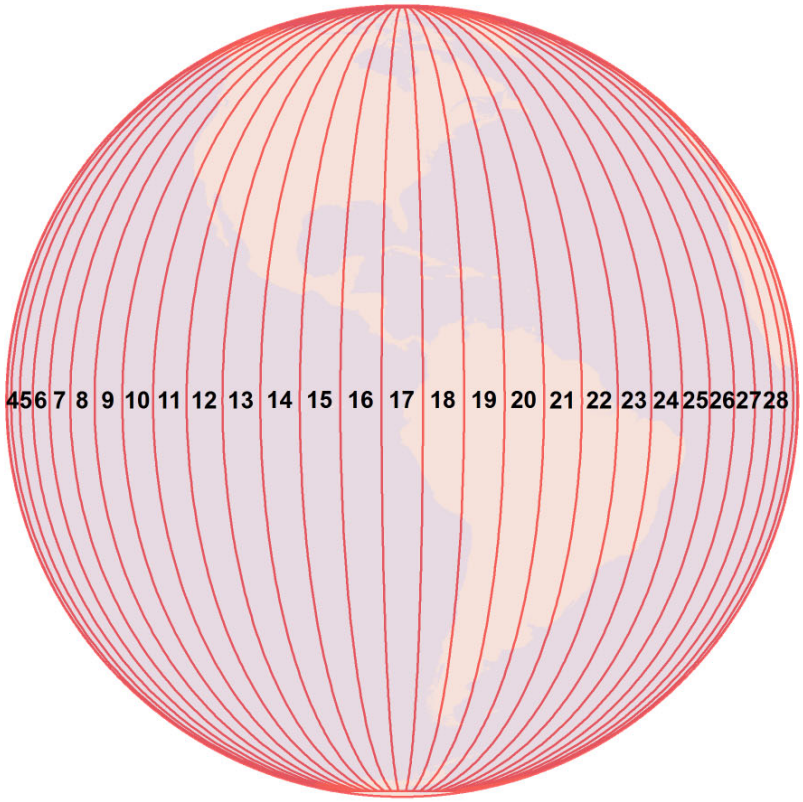


One UTM zone (6° wide)

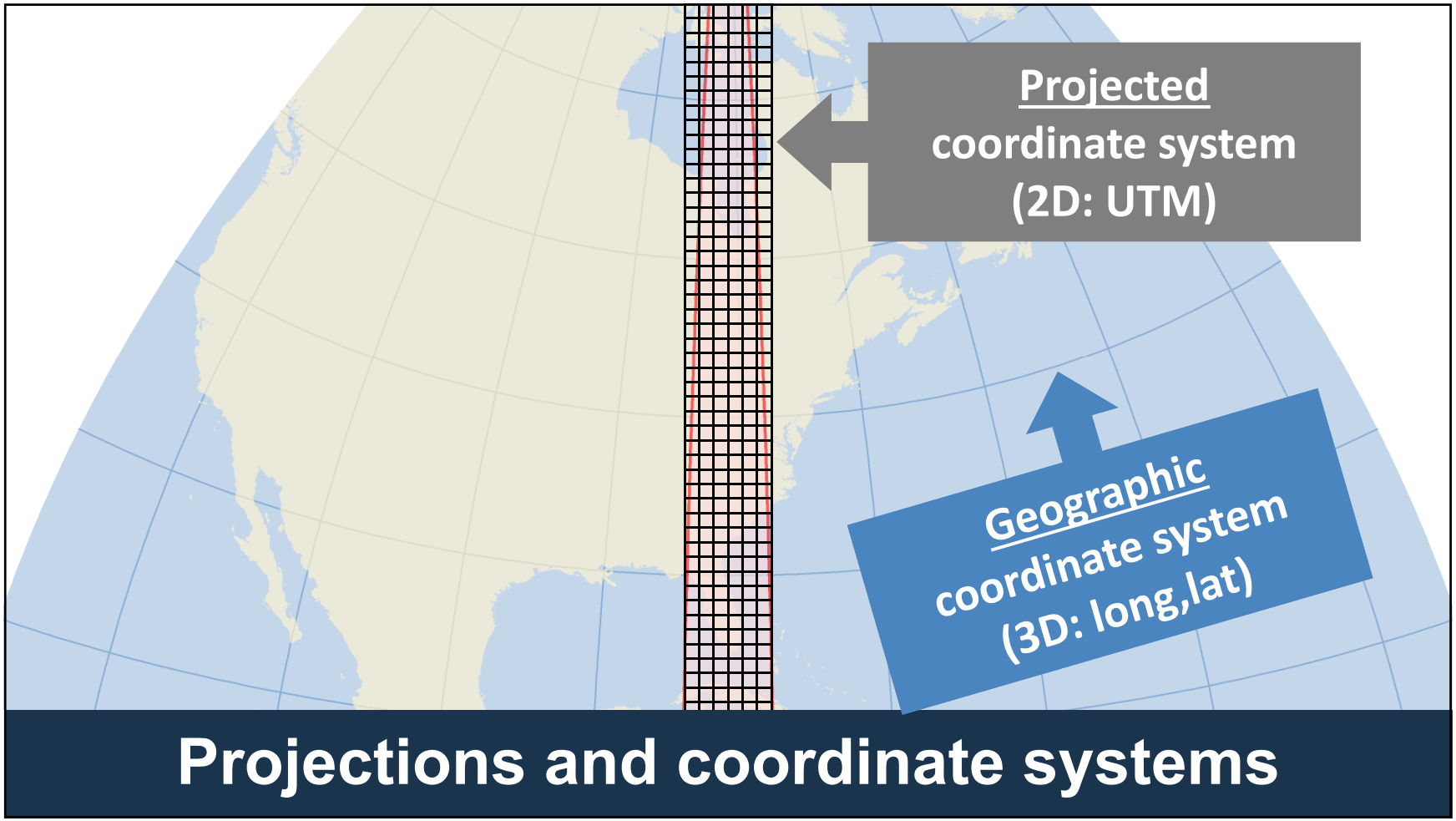


(adapted from Lo and Yeung, 2006)

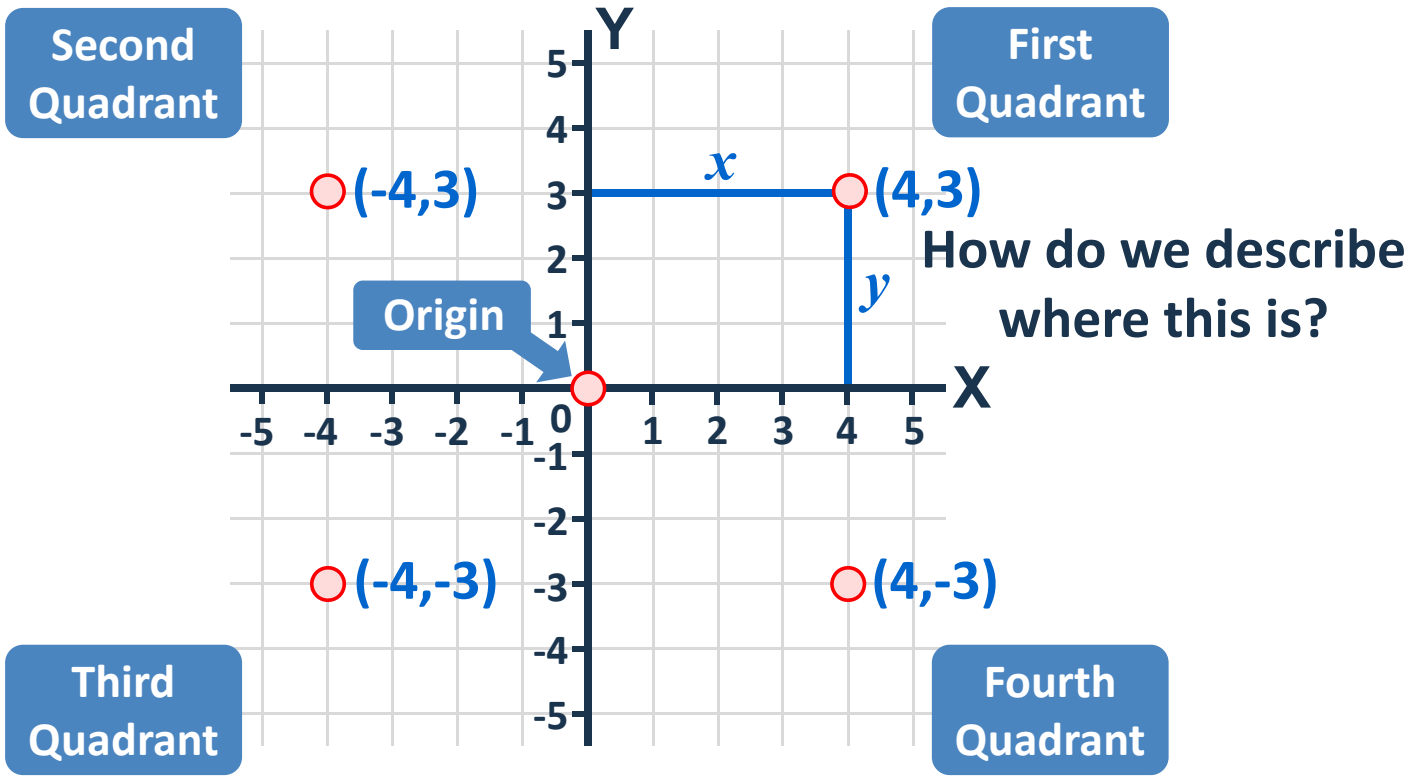
Rotate cylinder, create new zone



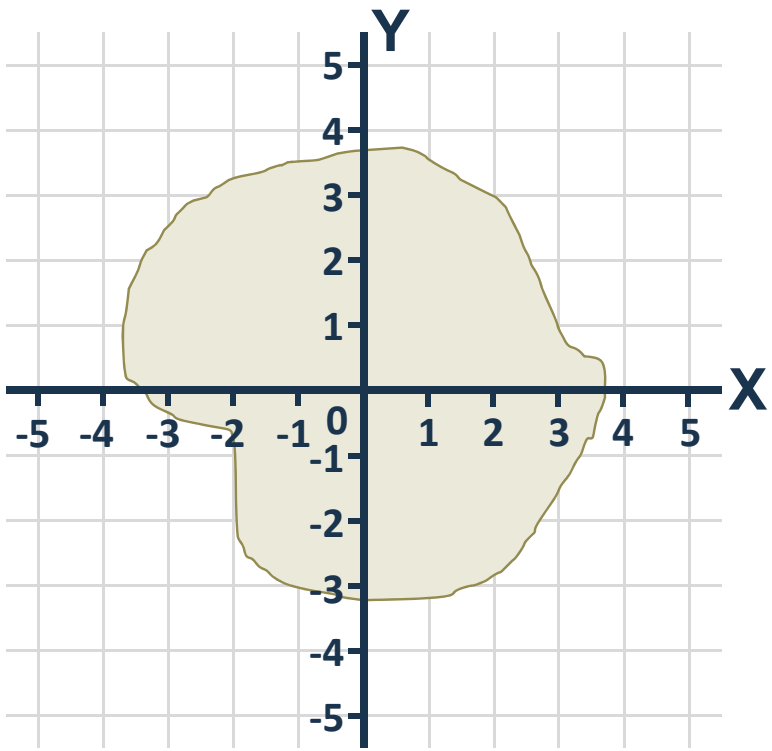
UTM zones



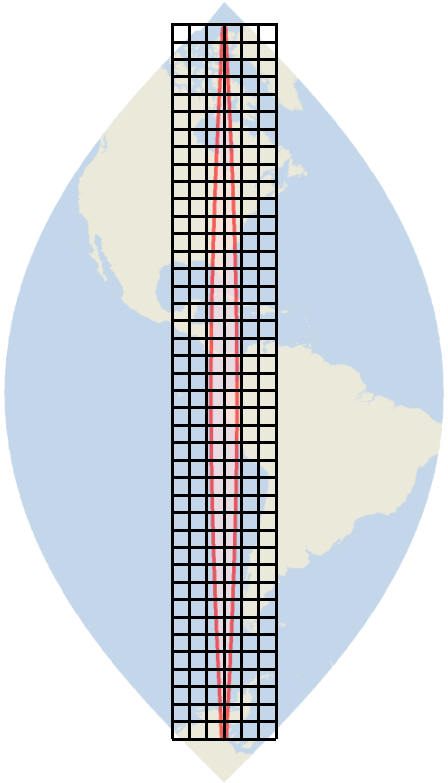
Projections and coordinate systems



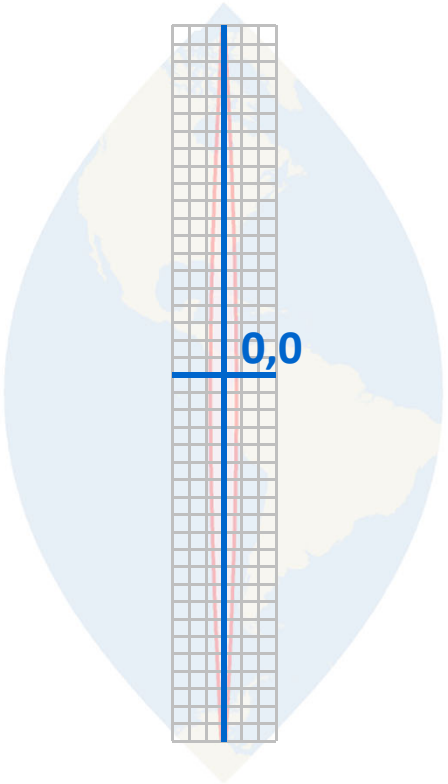
Plane rectangular coordinate system



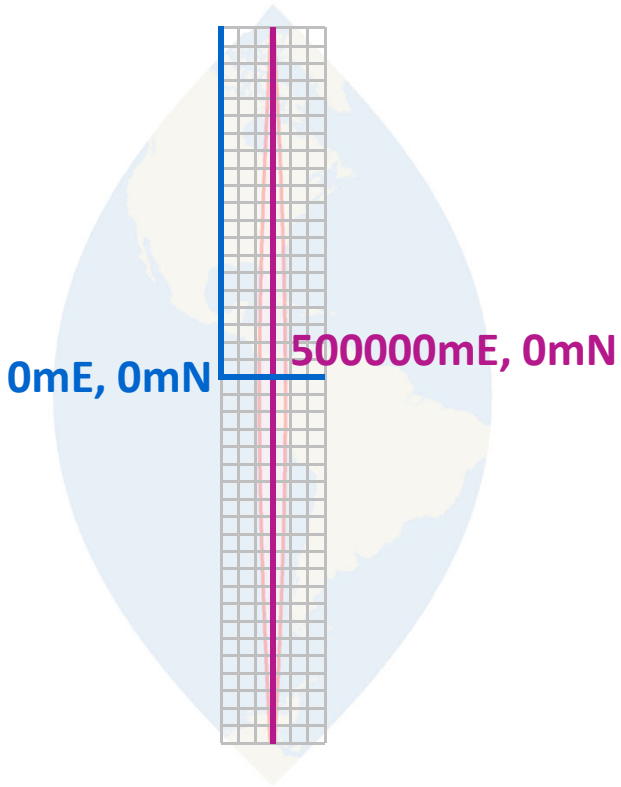
Staying positive!



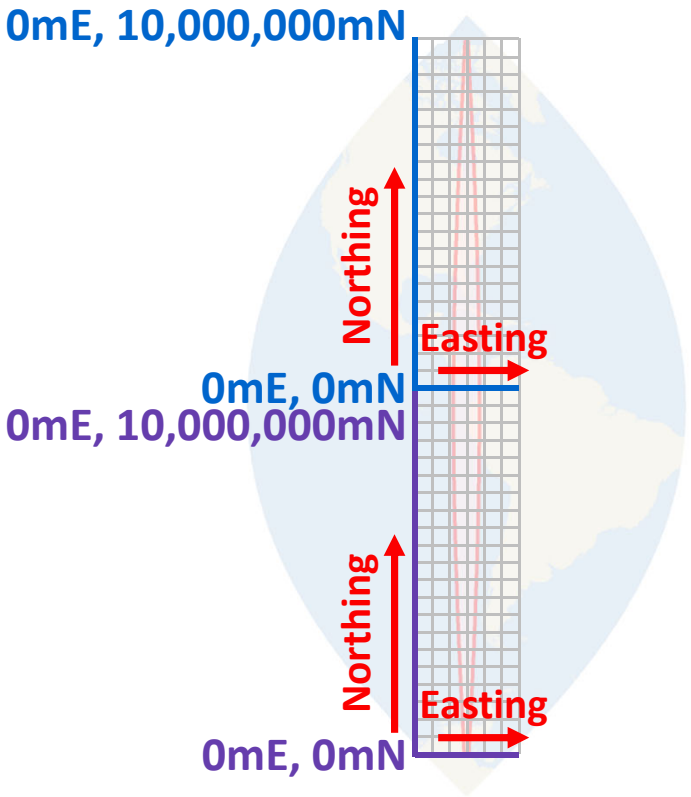
UTM coordinate grid



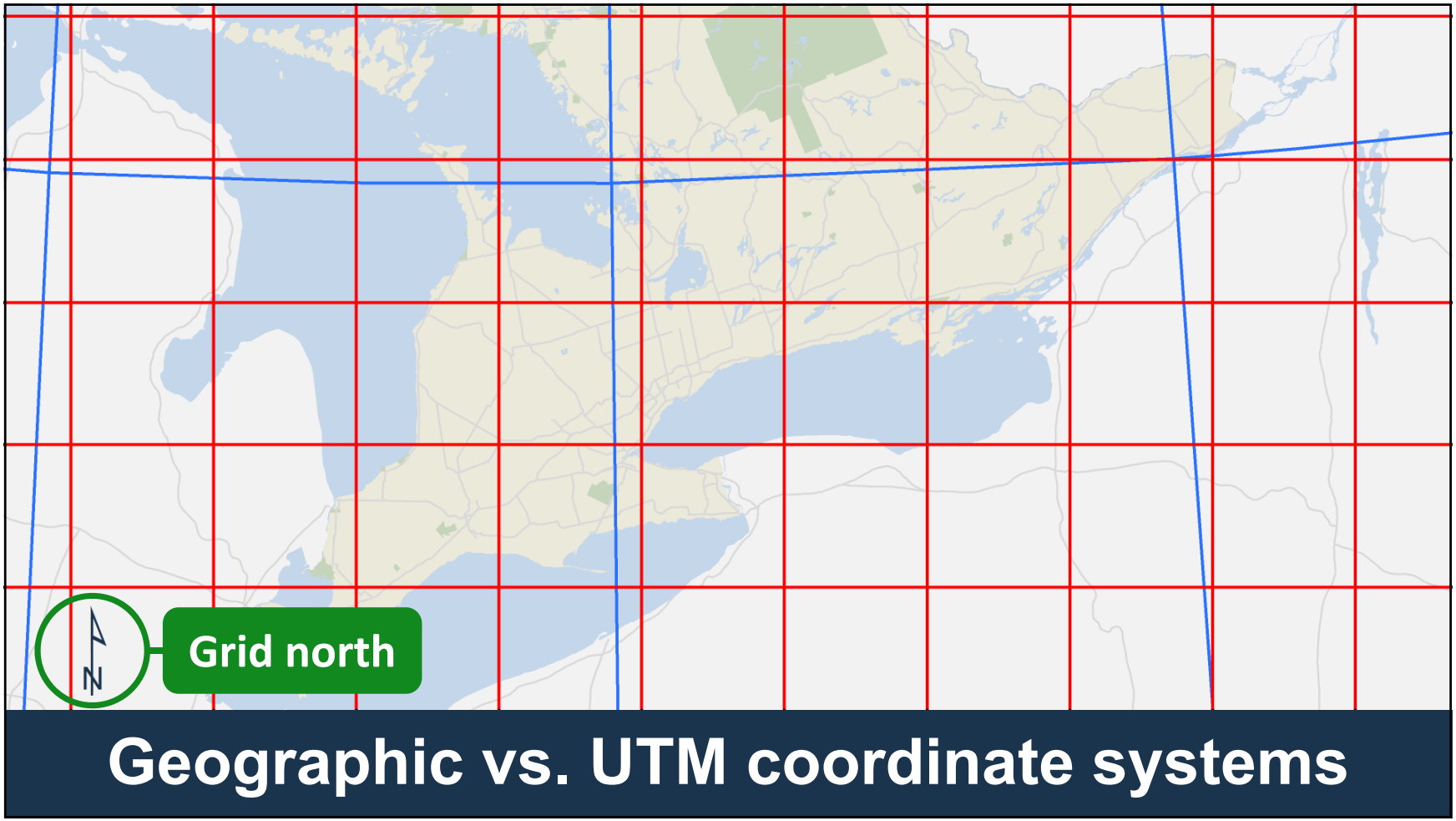
Where origin would normally be…



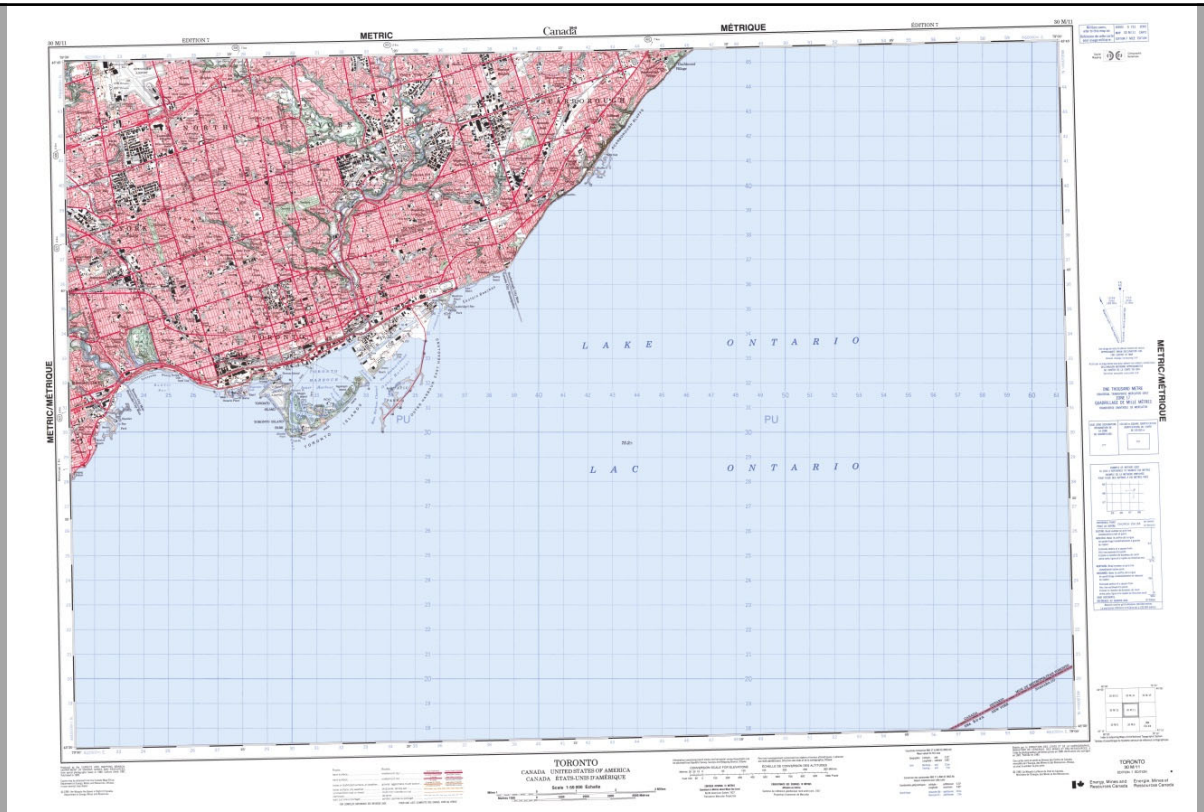
False easting



North vs. South hemispheres

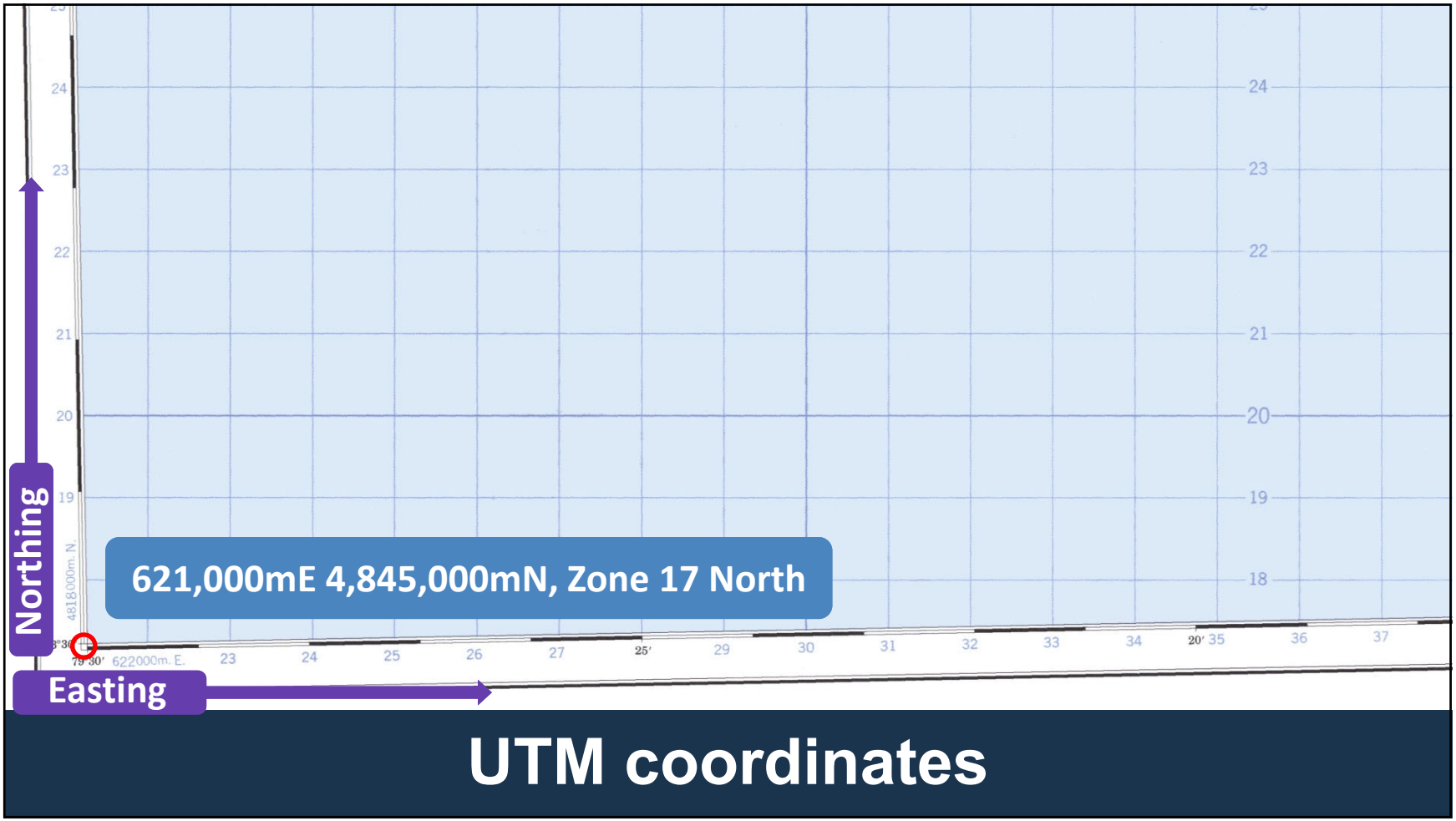


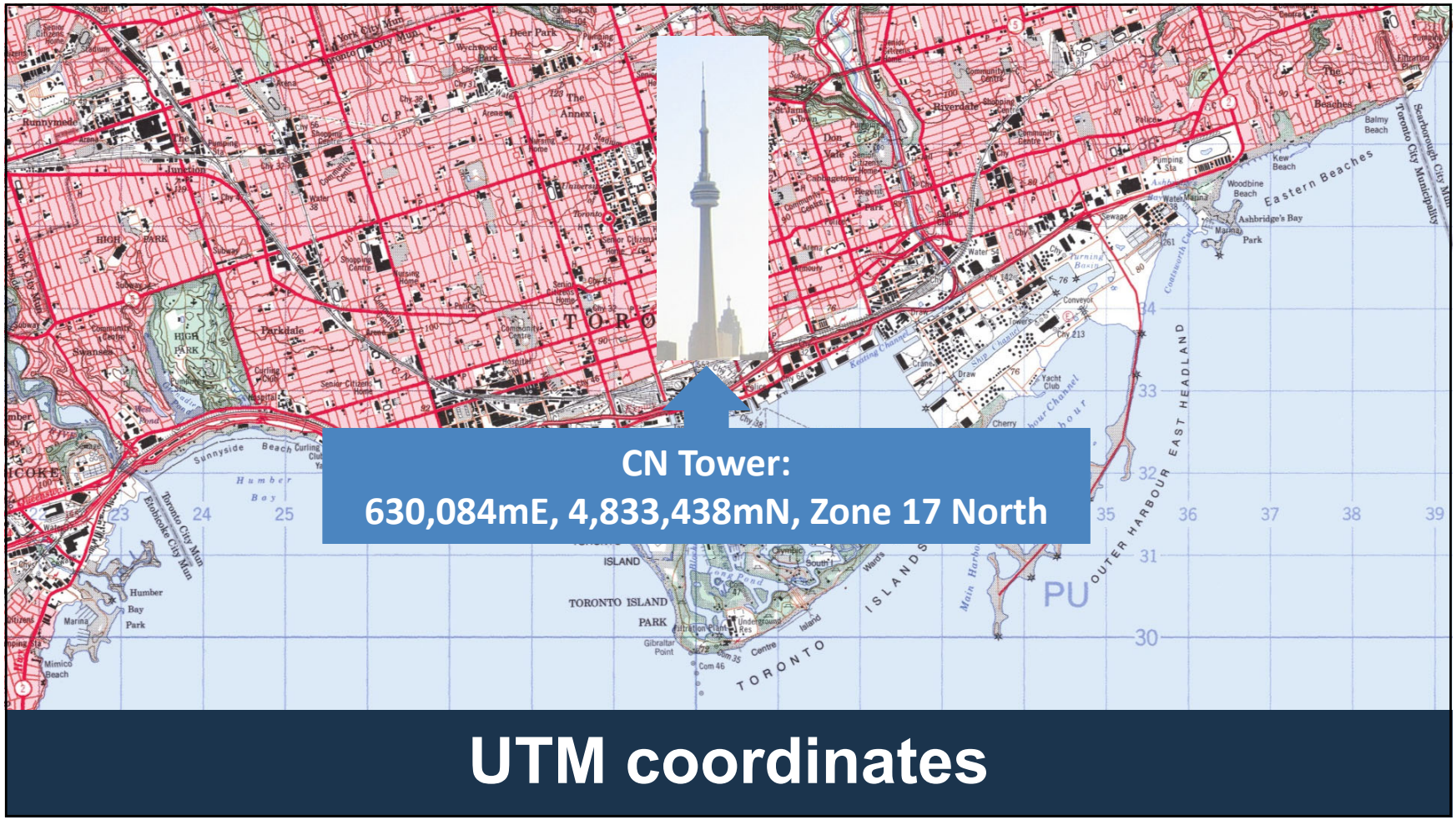
Geographic vs. UTM coordinate systems



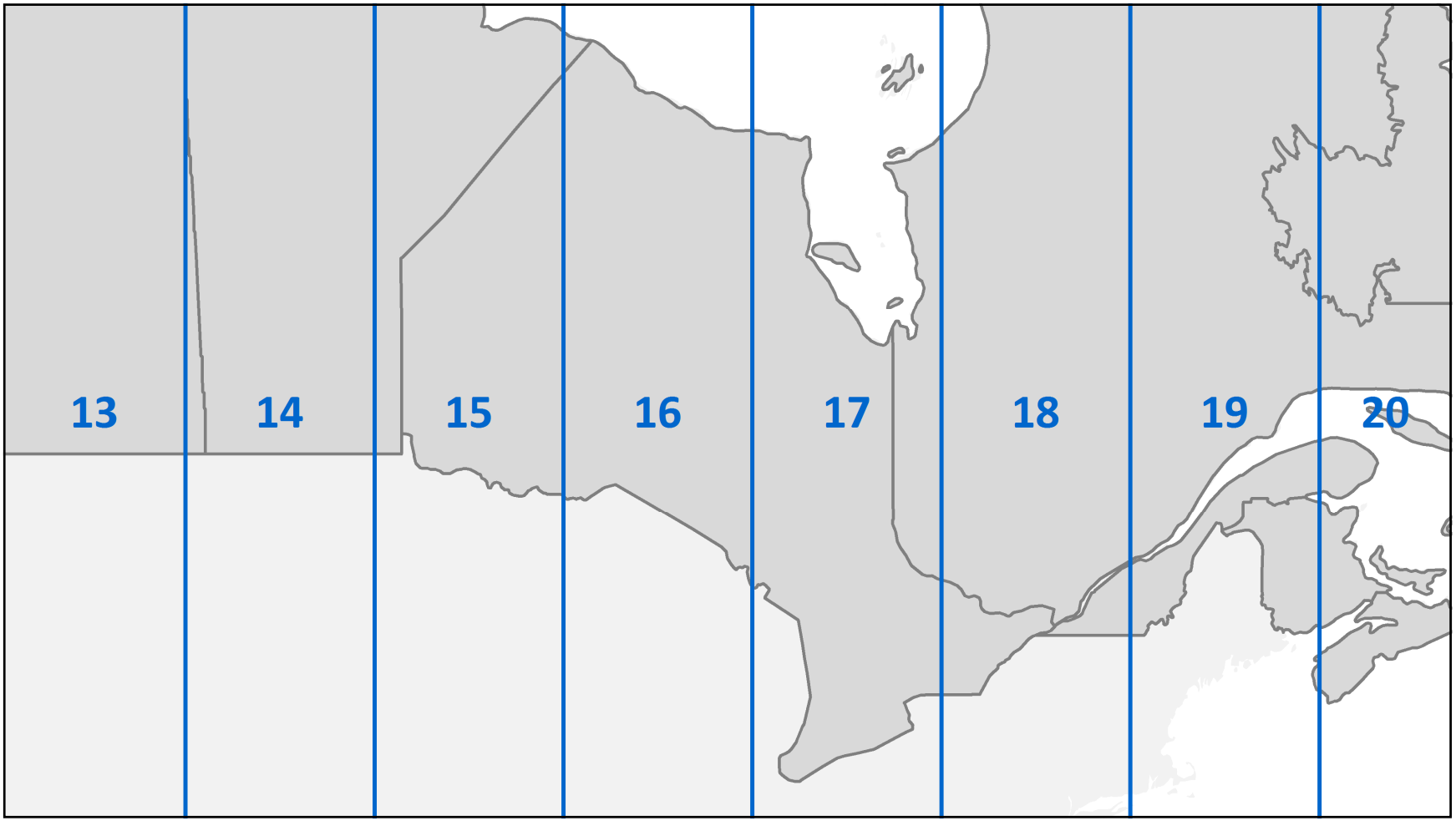
can-rncan/ess-sst/cb864dc7-25a1-5136-57f4-c095ce1c6a6d.html

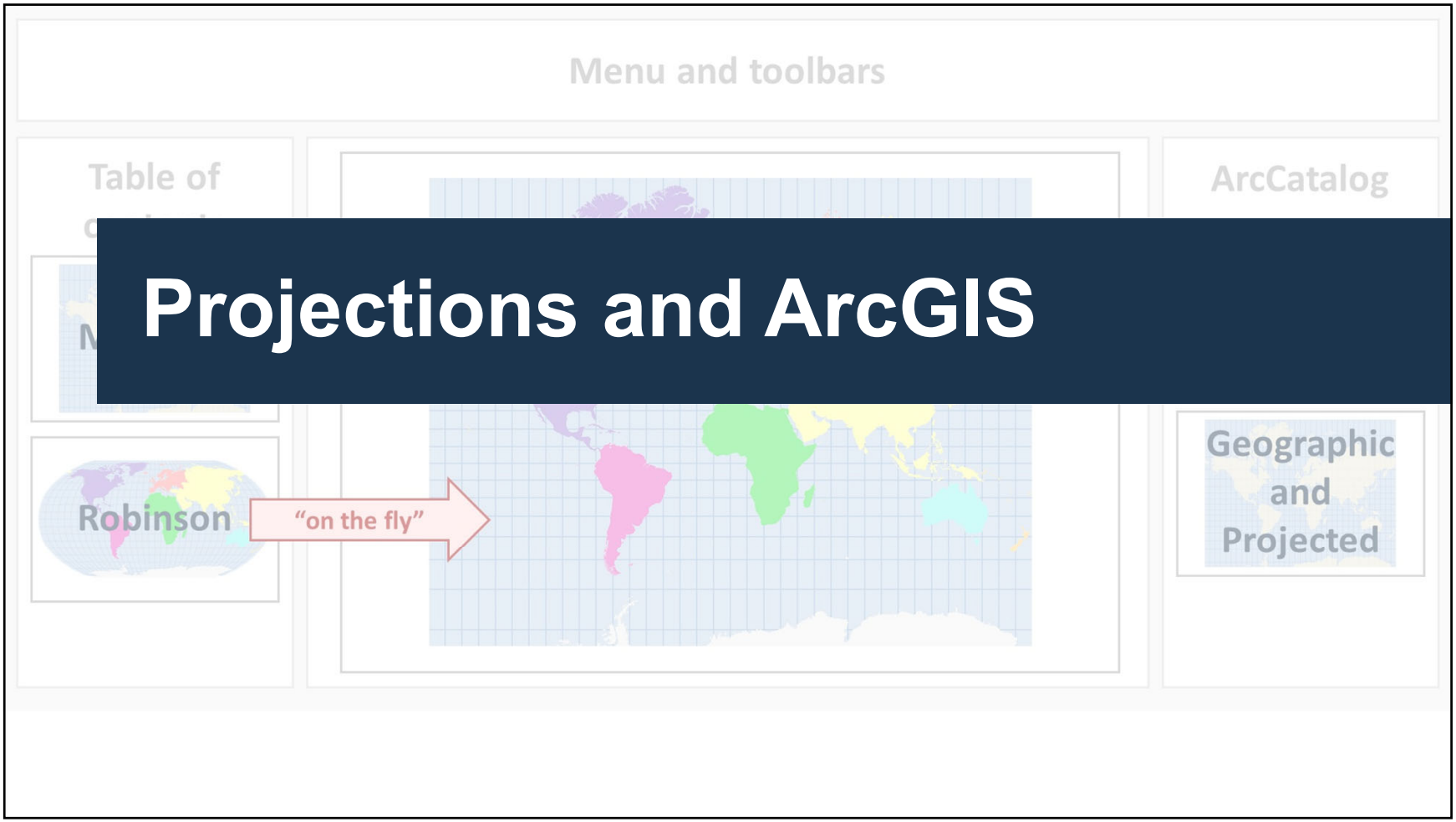
National Topographic System (NTS) map



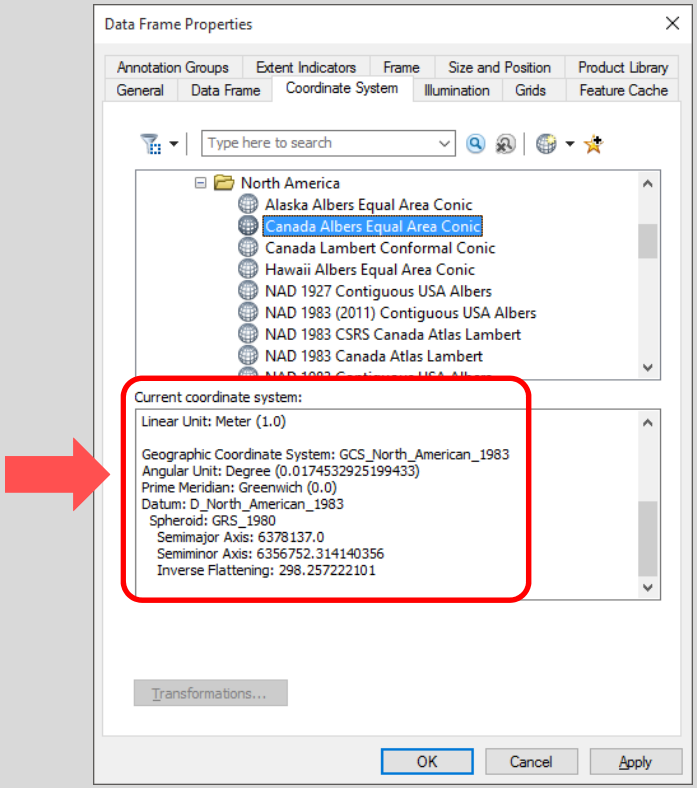


UTM coordinates

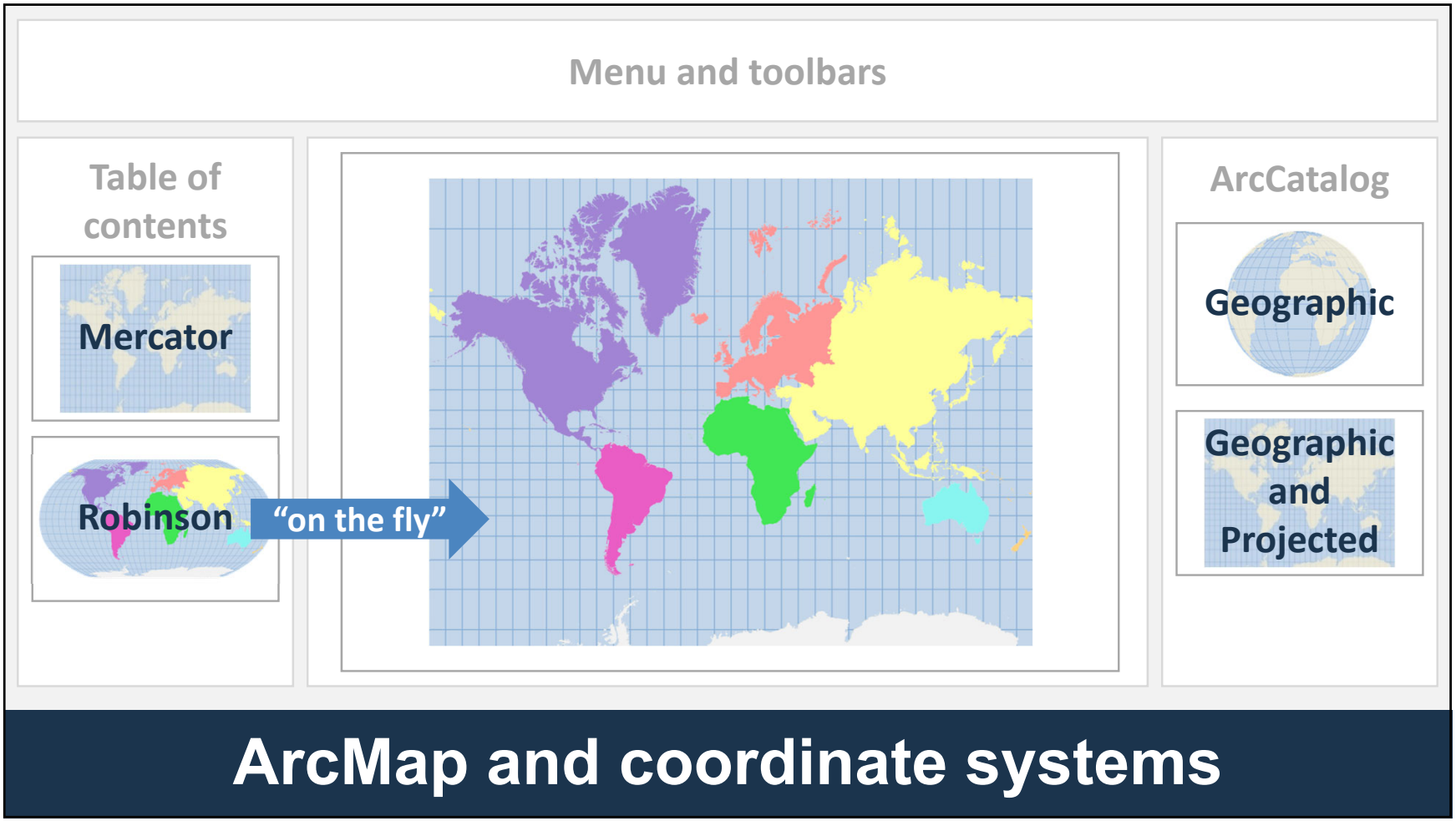




Projections and ArcGIS



Projected Coordinate System



Projection changes to data files

- Data can be saved to new file in new projection
- Coordinates in the data file are recalculated and adjusted to match the new projection
- You can’t always transform it “back” to exactly the same coordinates due to rounding errors.

To avoid errors…

- Exchange GIS data in a 3D geographic coordinate system, not a 2D projected coordinate system