Introduction to Map Projections

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20240920, Soracco
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2020, Soracco
2019, Soracco

This Training

- Expands on information discussed in the GIS modules of the *NOAA CoastWatch Satellite Training Course*

- *Useful references:*
  - *USGS: JP Snyder, Map Projections: A Working Manual: https://pubs.usgs.gov/publication/pp1395*
  - *ESRI ArcGIS Pro: https://pro.arcgis.com/en/pro-app/latest/help/mapping/properties/coordinate-systems-and-projections.htm*
  - *NSIDC: https://nsidc.org/data/user-resources/help-center/mapping-and-gridding-primer-points-pixels-grids-and-cells*

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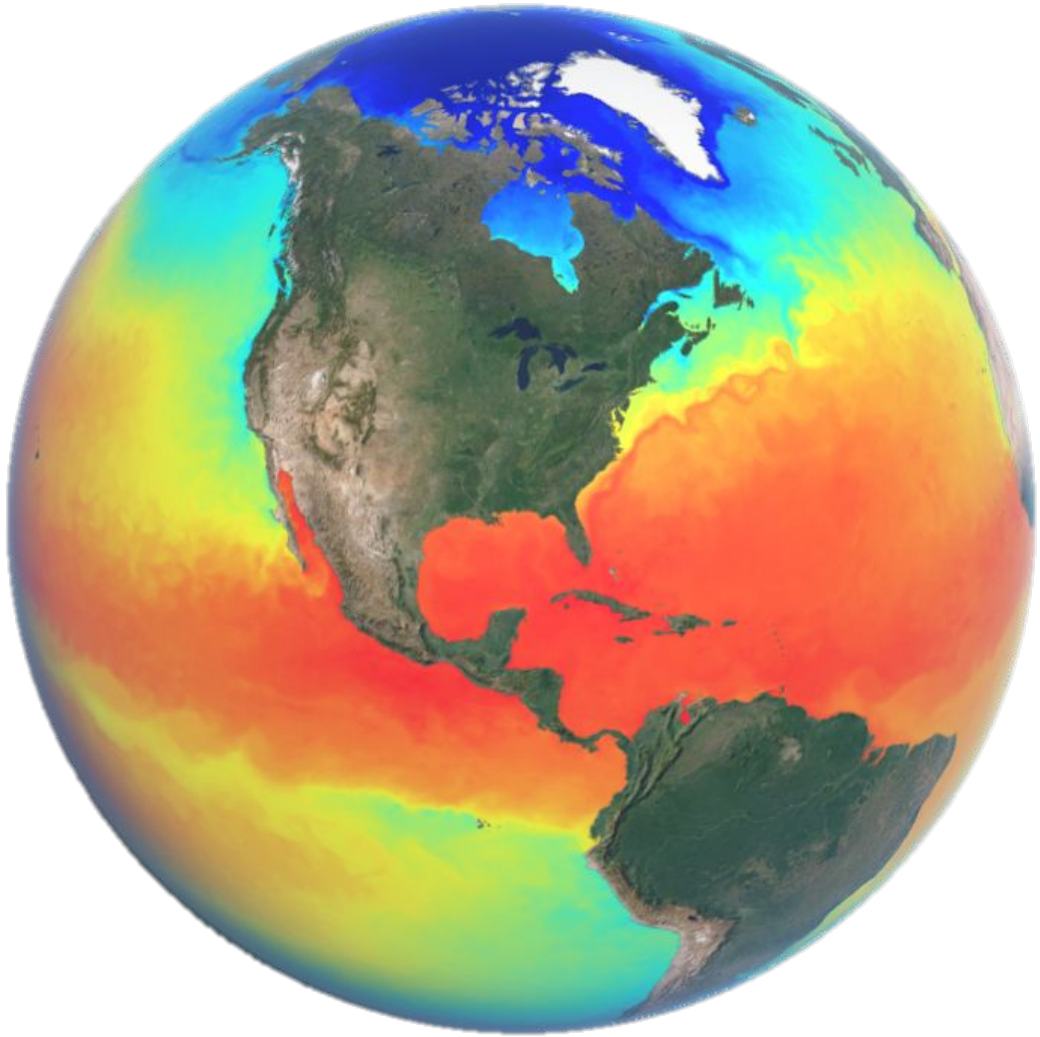
Earth

- Is not flat
  - [until projected]
- Is not a sphere



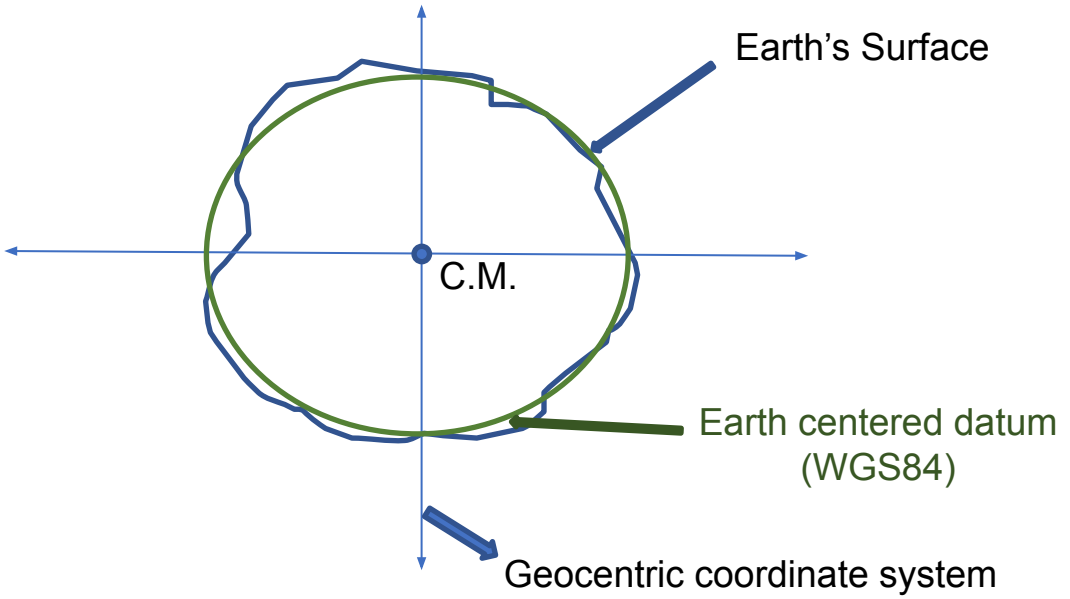
Earth Coordinate Systems

- Horizontal (surface)
  - Geographic
    - Geographic (Lat/Long)
    - Geodetic (map projections)
  - Projected (Geodetic)
  - Local
- Vertical (altitude / depth)
  - Gravity-based (Mean sea level)
  - Ellipsoidal (Mathematical)

Typically used for GLOBAL data and needs to match the same ellipsoid used in the Horizontal system (i.e. WGS84)

And there is a difference between WGS84 and WGS 84.
WGS84 is an alias of the ellipsoid (EPSG::7030). WGS 84 can be referring to the ellipsoid, a geodetic coordinate system (EPSG:4326) or datum (EPSG::6326)

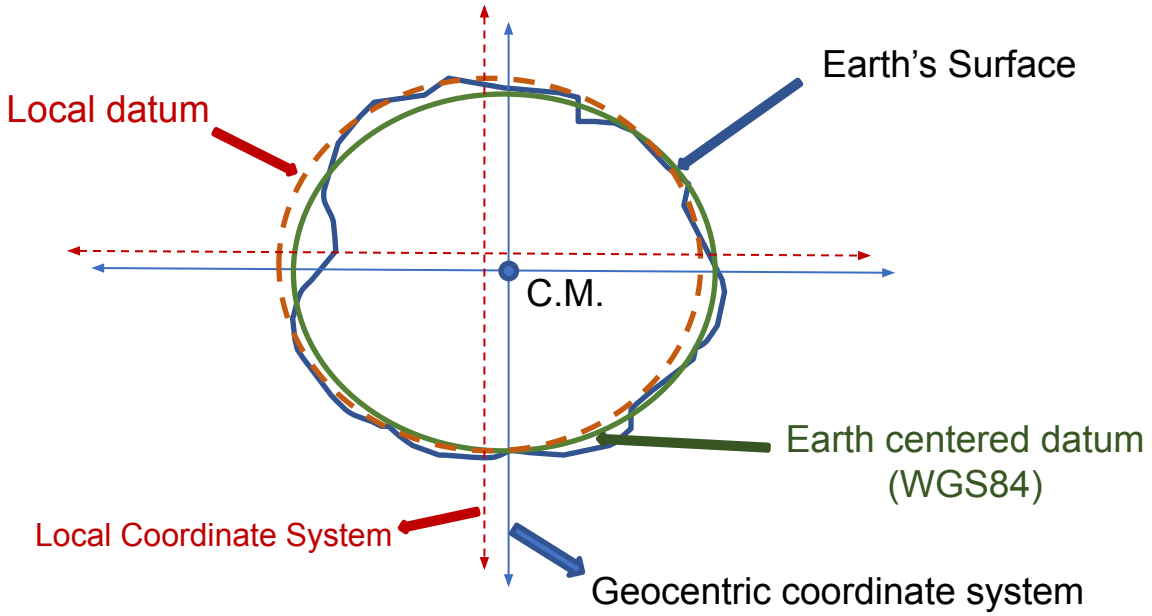
Datum



- Spheroid/Ellipsoid
- Defines frame of reference
  - Measurements
  - Latitude/longitude lines
- Chosen for best accuracy [at a given scale]
  - Global - geocentric datum using the Earth's center of mass (WGS84)
  - Local datums are matched to the surface
- A 'datum shift' is a change of datums while maintaining projection

So you can have a different latitude and longitude for the same point?

Datum



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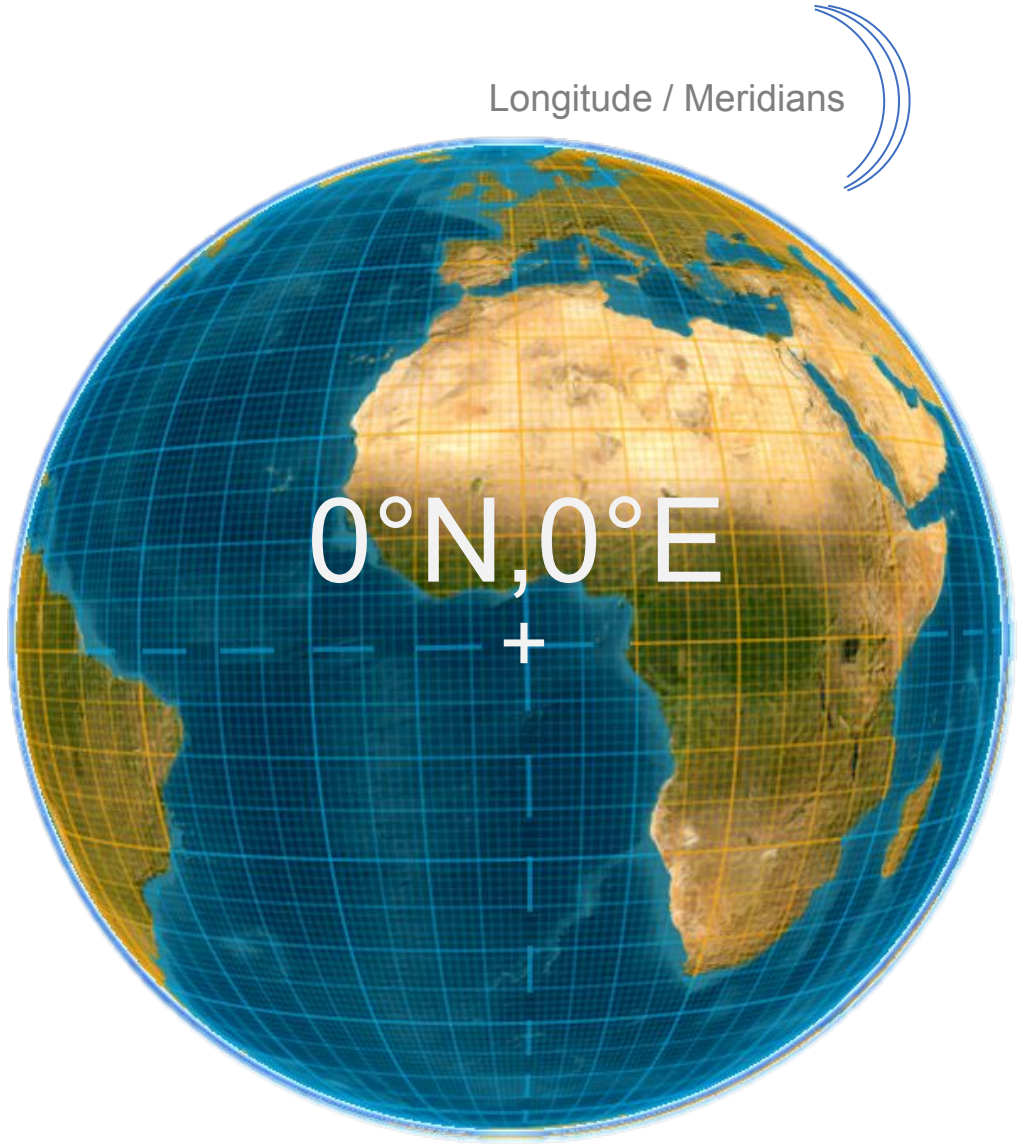
So you can have a different latitude and longitude for the same point?

Geographic Coordinate System

- 3-D Spheroid/Ellipsoid
  - Datum
- Latitude and Longitude
  - Forms graticules at surface
- Angles (degrees) measured from the Earth's center to the surface
- Not uniform units of measure – equator is the closest you get



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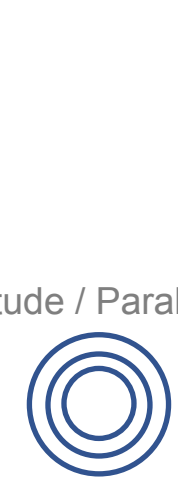
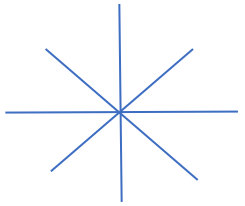
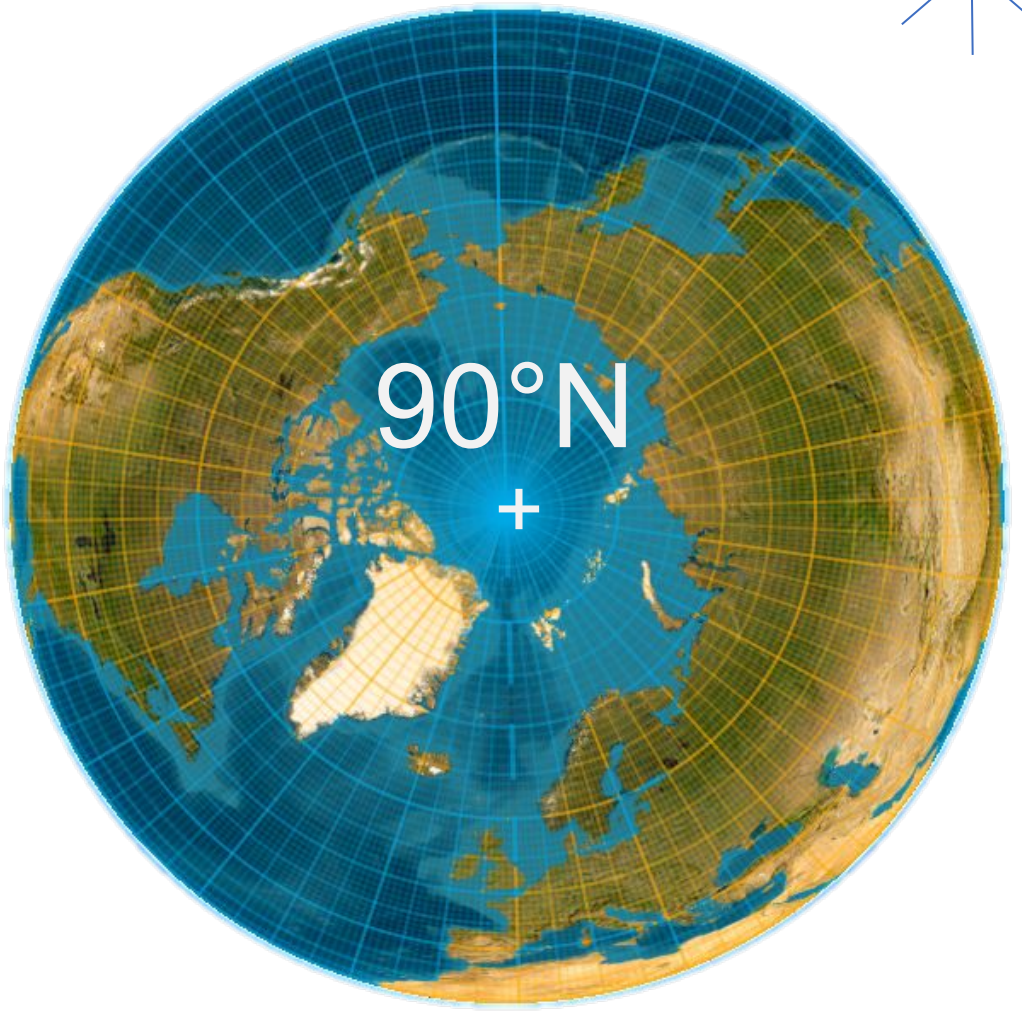
Latitude / Parallels



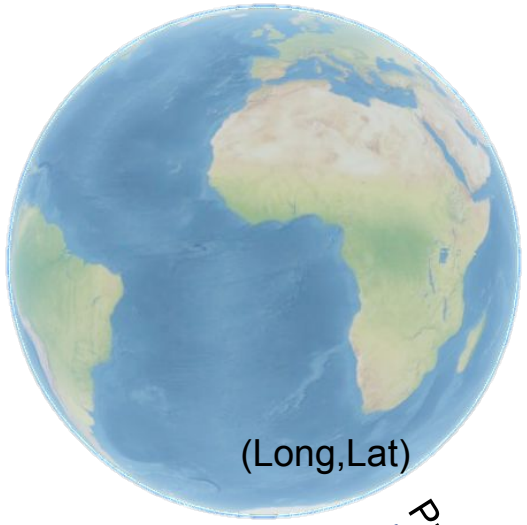
Longitude / Meridians





Projected Coordinate System

- 2-D Gridded
- Mathematical transform
- X,Y Coordinates
- Distortion

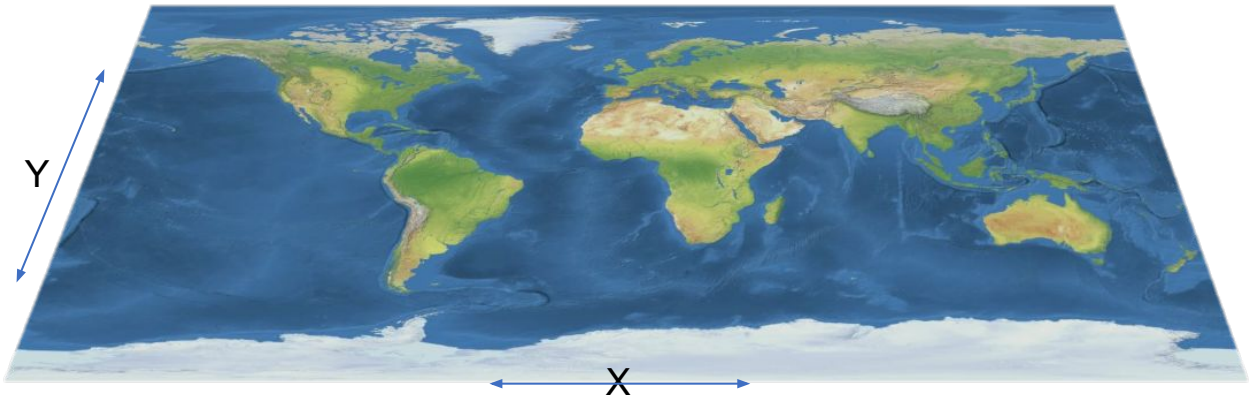


Spherical to Planar coordinates

Projection process
Mathematical Transformation

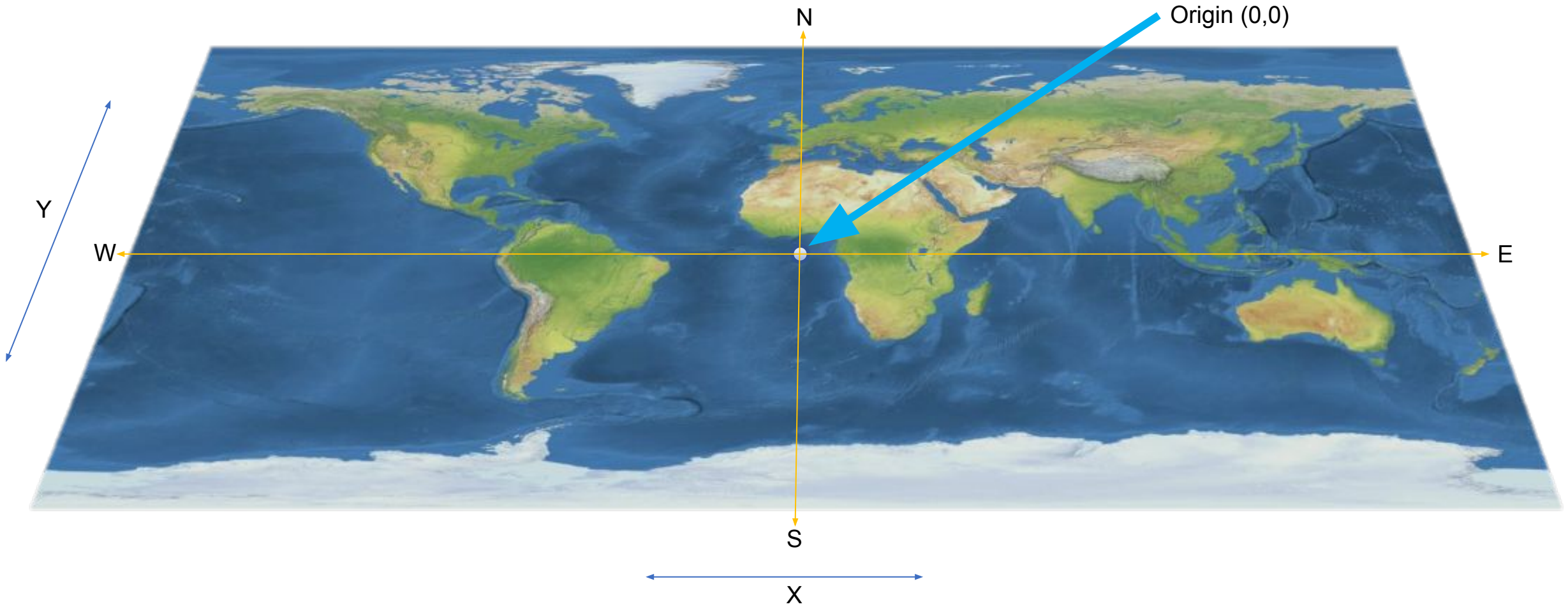
(X,Y)

Distortion



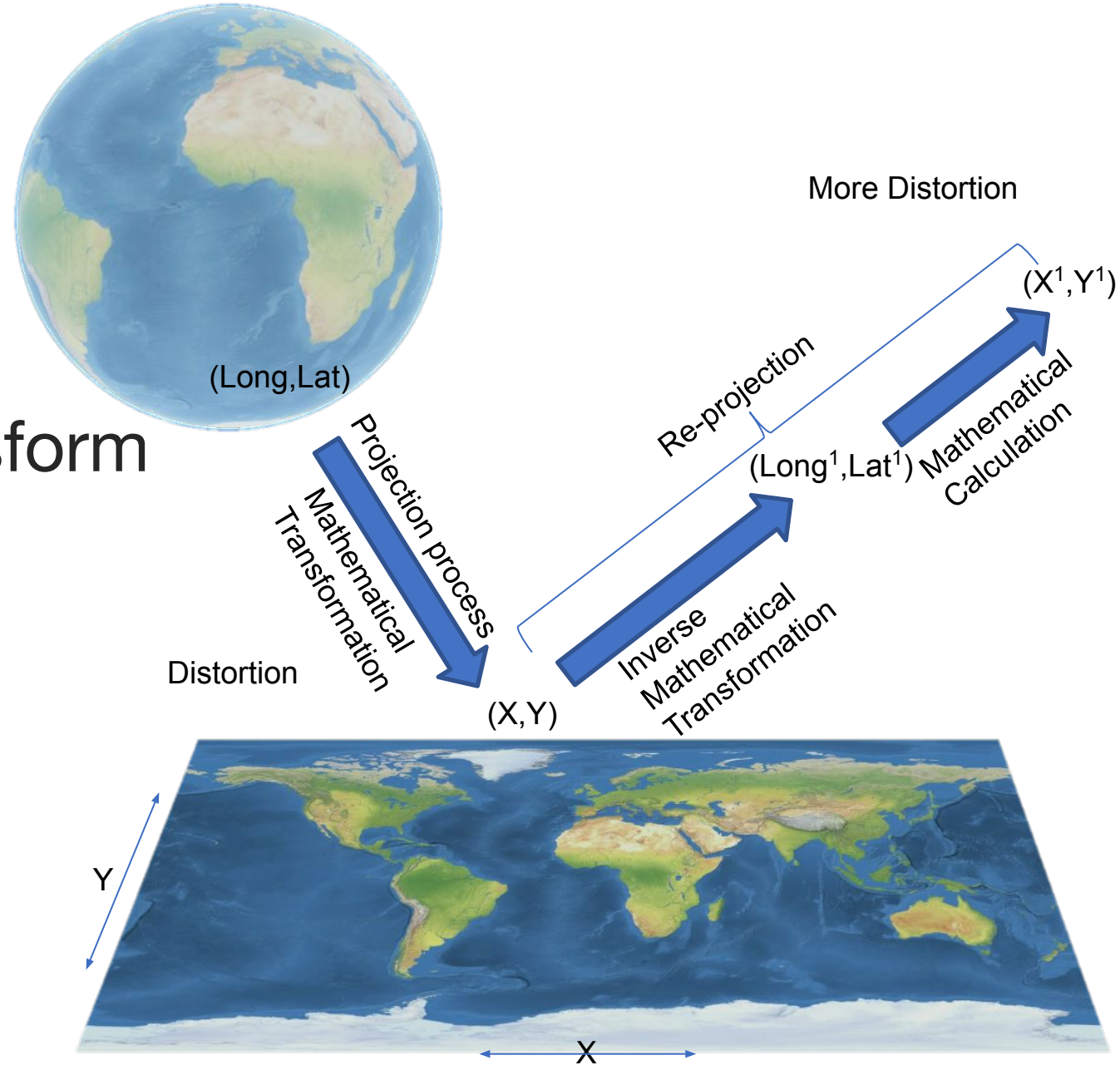
We have a map!

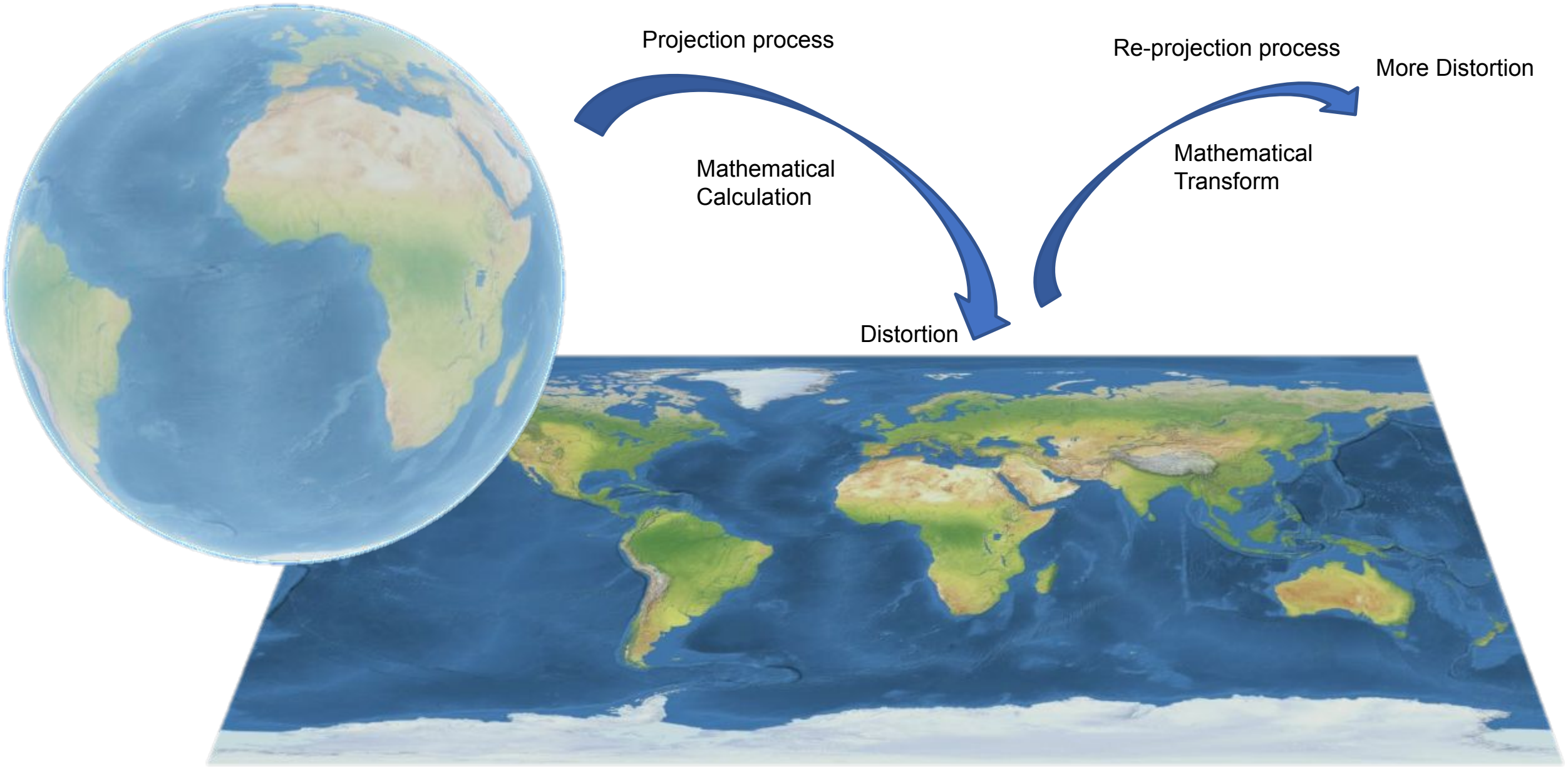
Scale error is minimized at the map's origin or when a latitude of True Scale is used (projection dependent)



Re-Projection

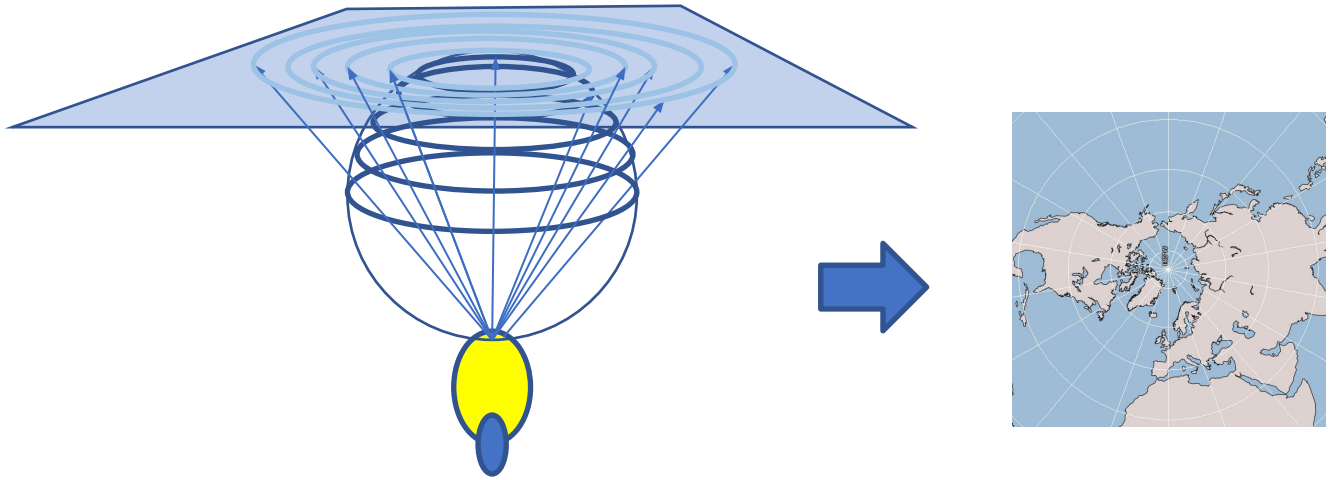
- 2-D
- Inverse Mathematical transform
- X,Y => Long,Lat => X^1,Y^1
- More Distortion



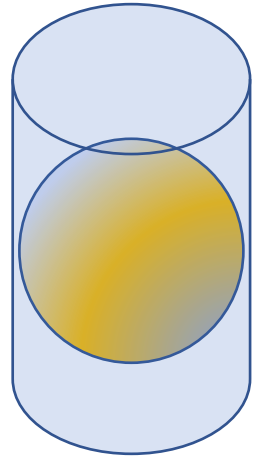

Projection process
Mathematical
Calculation
Distortion
Re-projection process
More Distortion
Mathematical
Transform

Construction of Projections

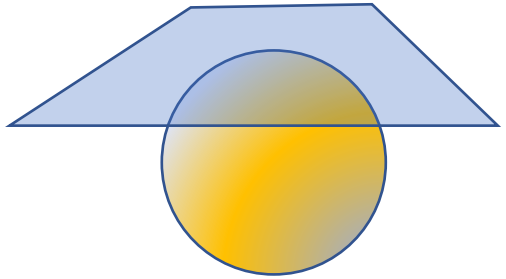
"Imagine a light source projecting the graticule pattern onto a surface"



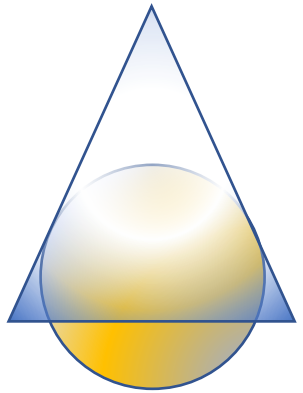
Map construct types
(not all are shown)



Cylindrical

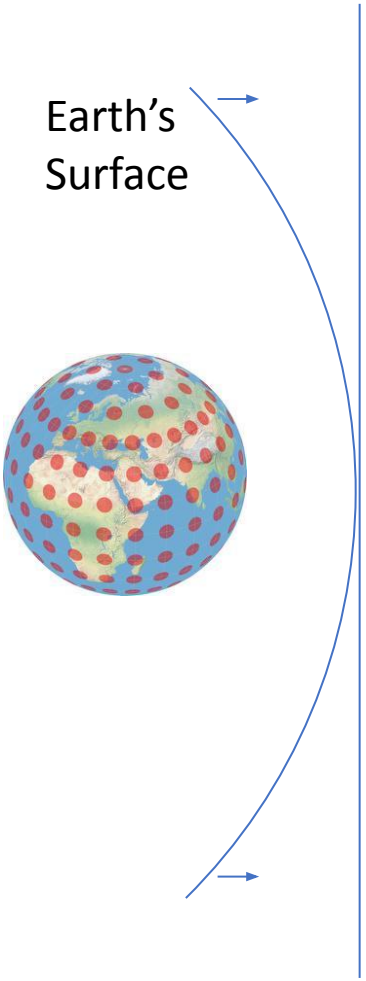


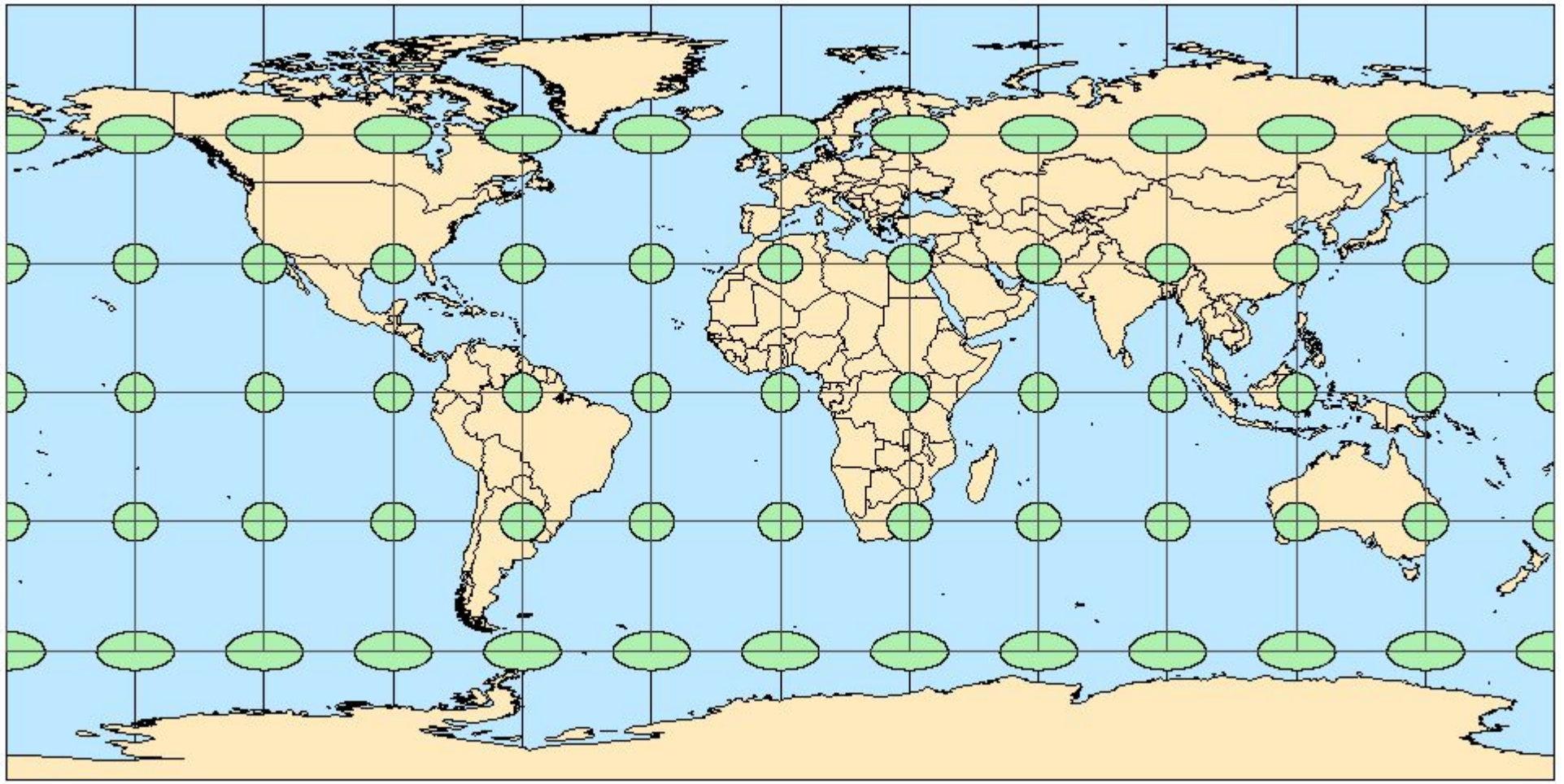
Azimuthal



Conic

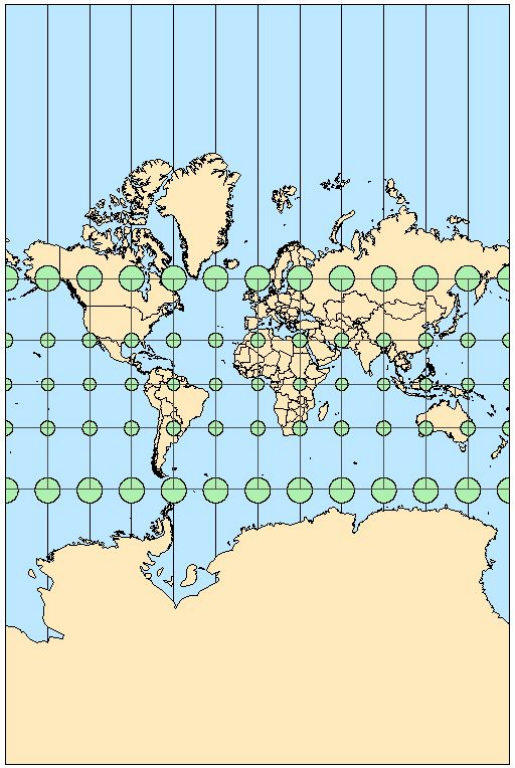
Geographic (WGS84)



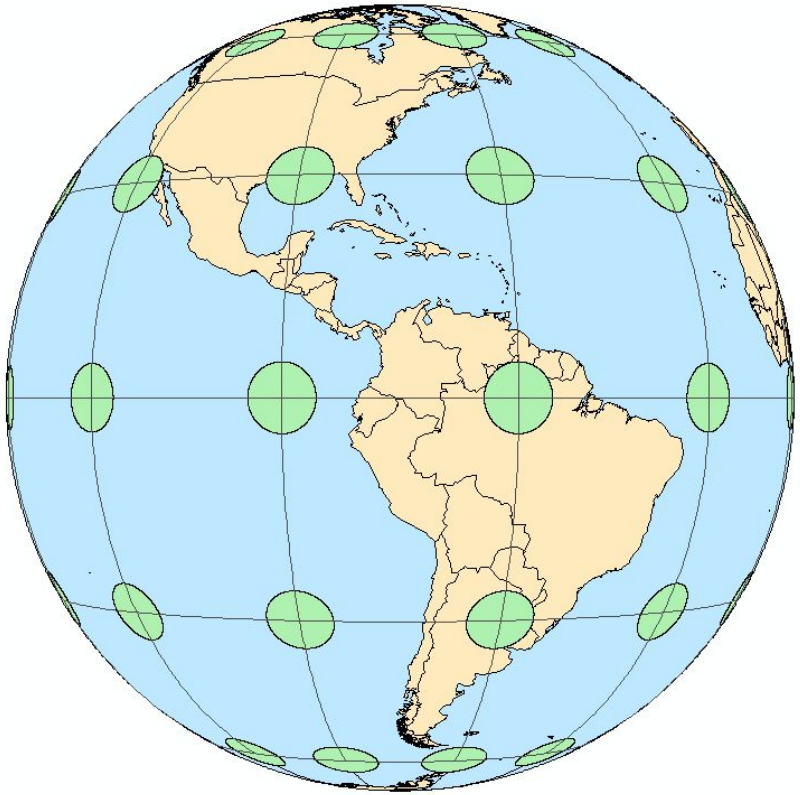


Tissot's indicatrix of circles illustrating distortion across a map

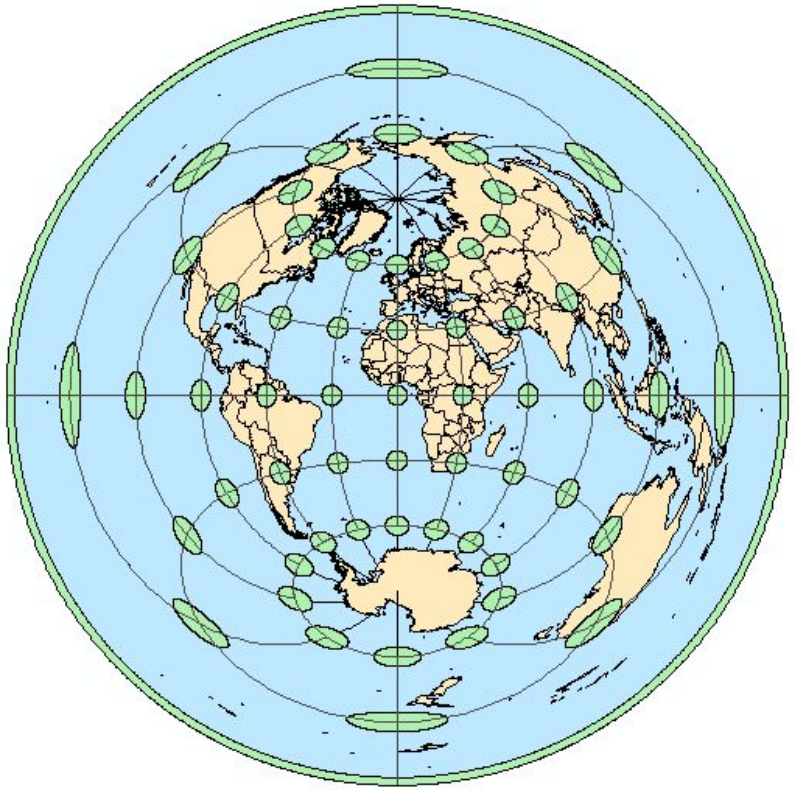
Mercator (WGS84)



GOES-16 (GRS80)

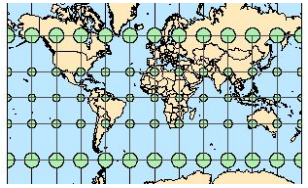


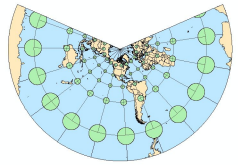
Azimuthal Equidistant



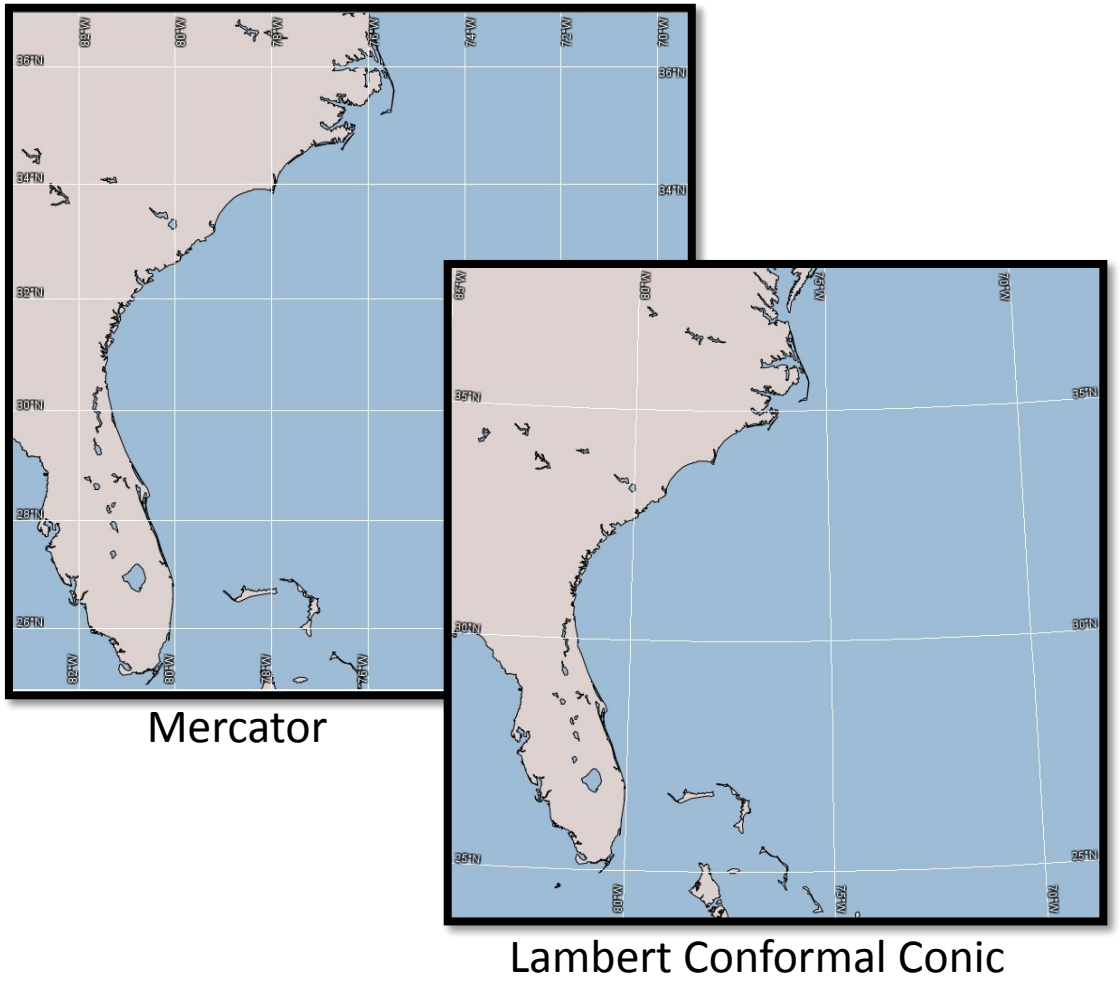
Tissot's indicatrix of circles illustrating distortion across a map

Satellite Data Product Projections - Conformality





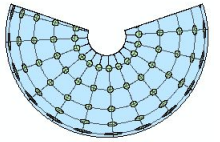
- Shape is preserved
- Representative of actual feature
- Useful for preserving shape
  - Mercator
    - Straight lines have constant bearing
  - Lambert Conformal Conic
  - Stereographic



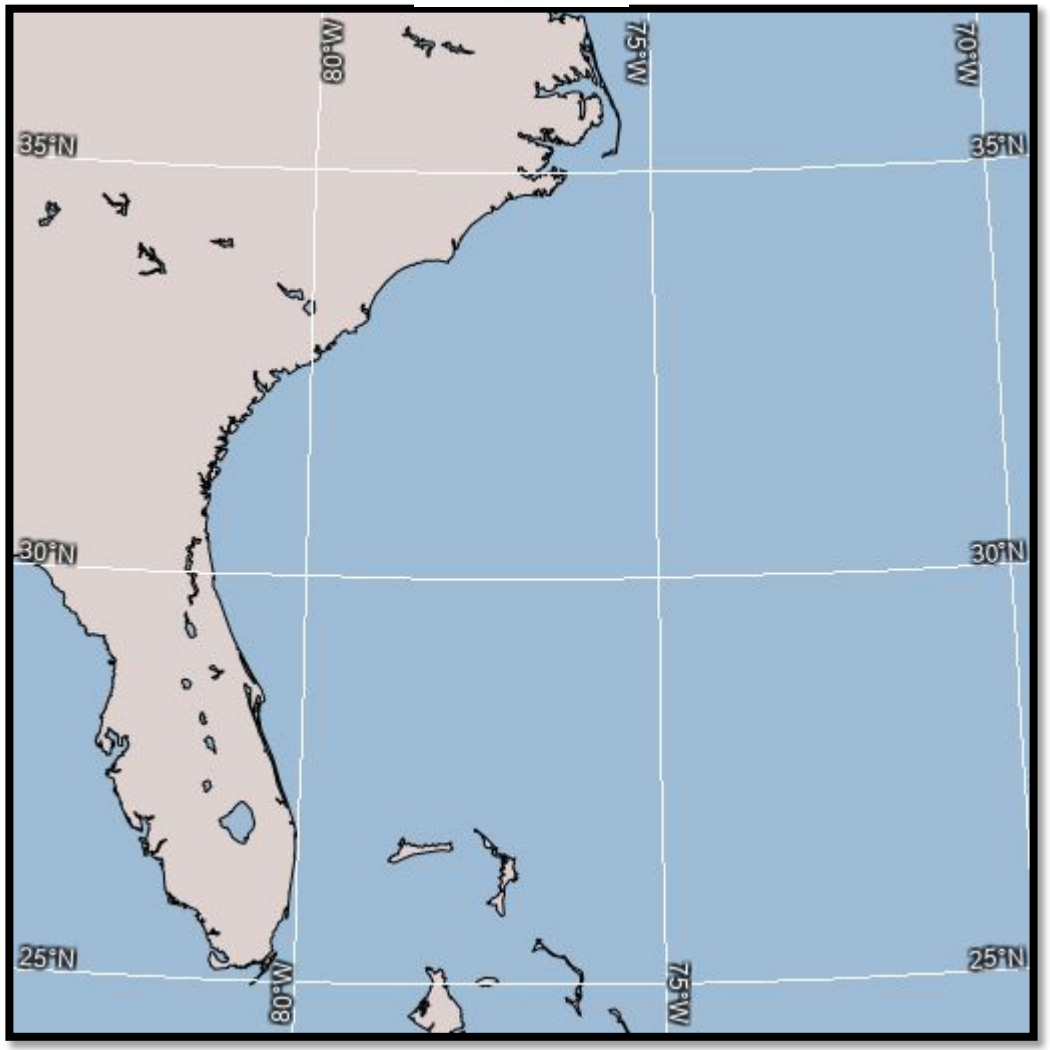
Mercator

Lambert Conformal Conic

Satellite Data Product Projections - Area



- Area is preserved
- Area measurements consistent across map
- Useful for comparison
  - Albers Equal Area
  - Lambert Azimuthal Equal Area



Albers Equal-area preserves area

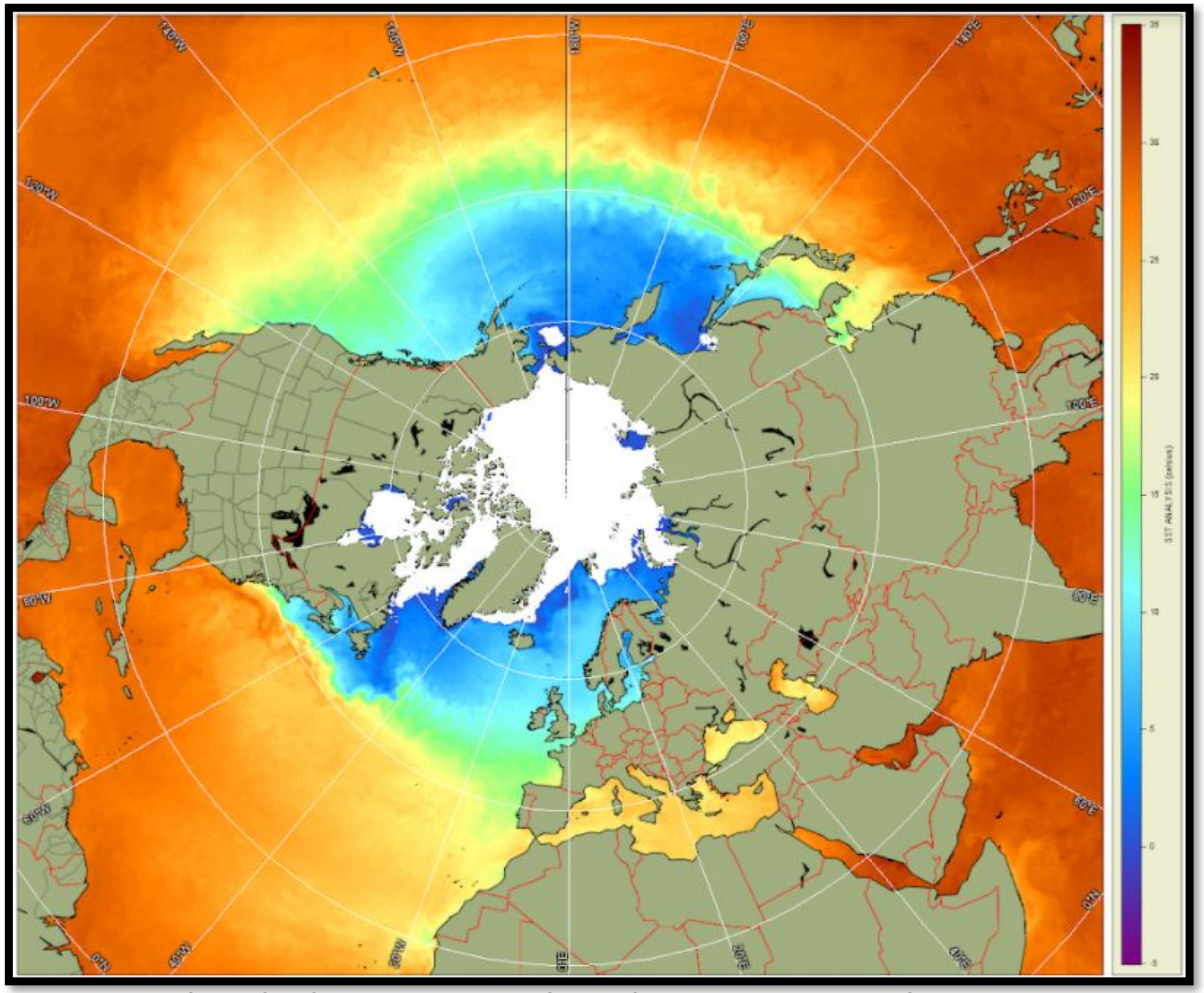
Choosing a Projection: Considerations

"What are you trying to do?"

- Purpose — **Presentation • Navigation • Comparison • Thematic**
- Properties — **Perspective • Equal-Area • Compromise • True Direction**
  Conformal • Straight Rhumbs • Equidistant
- Extent — **Global • Hemisphere • Ocean • Sea • Medium Scale • Large Scale**
- Location — **Equatorial • Polar • North/South • East/West • Oblique**

Choosing a Projection: Data

- Metadata
- Format
- Resolution
- Existing Projection
  - Coordinate system
  - Datum
- Preparation



NOAA Blended SST in North Polar Stereographic Projection

Choosing a Projection: Data ‘Inertia’

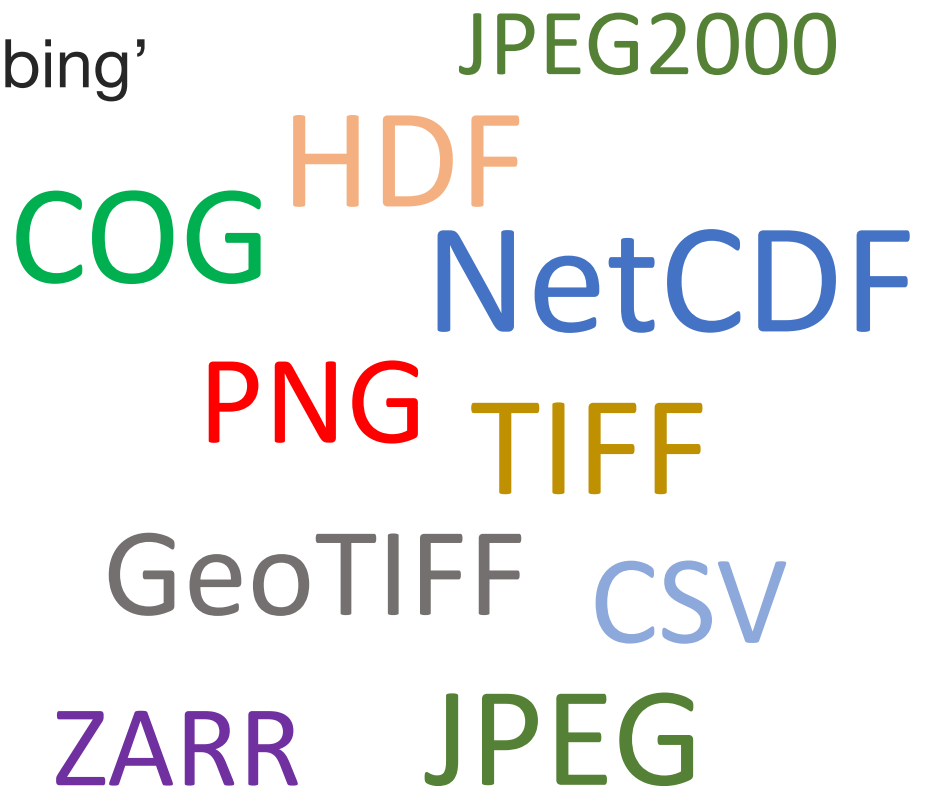
- Organizations may have selected a projection and have thousands of datasets using it.
- What projections are comparative data in?
- How much effort to reproject data?
- Is the difference between dataset projections minor or major?

Choosing a Projection: Metadata

- Information about the data – usually standardized
- Methods used in collection / processing
- Custodian / Point-of-contact
- License

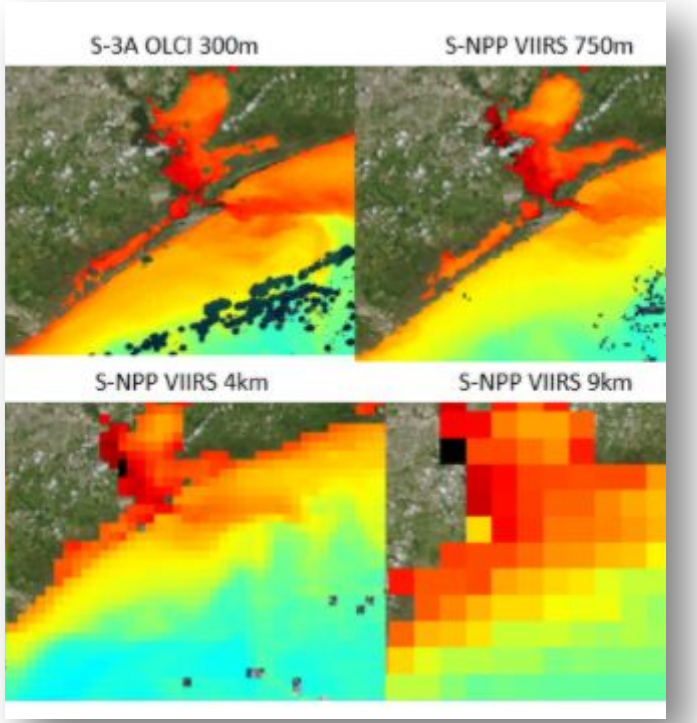
Choosing a Projection: Data Format

- Level of embedded metadata – ‘self-describing’
- Data storage
  - Scaling / Offset
  - Compression
- Geolocation Information
  - Tags
  - Attributes
- Complexity and Compatibility



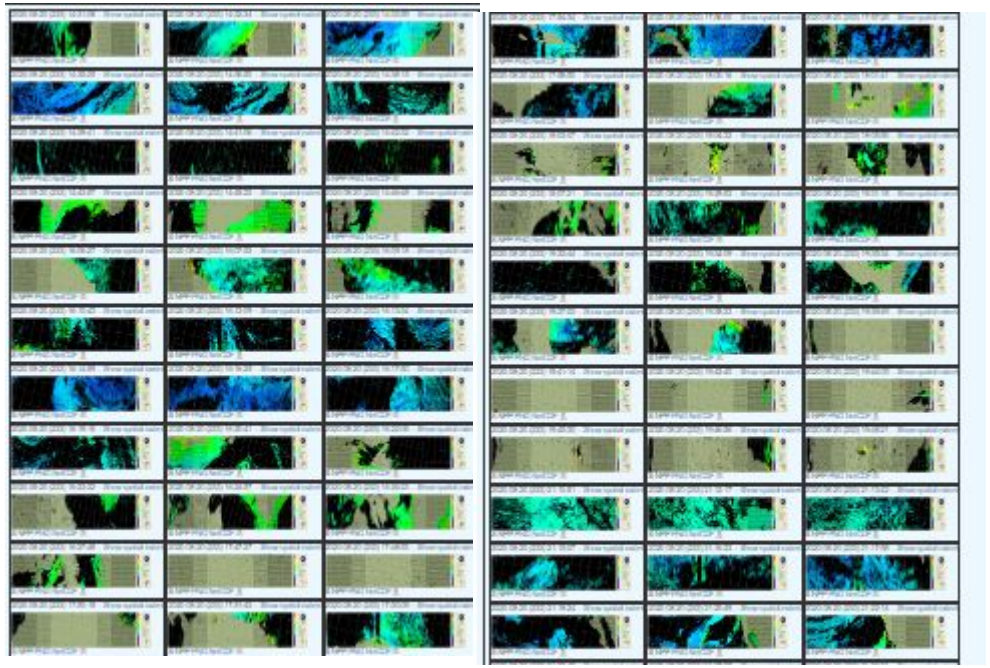
Choosing a Projection: Satellite Data Product Resolution

- Spatial resolutions
  - meters to hundreds of kilometers
- Temporal resolutions
  - Minutes to days, weeks, or months
- How are data combined?
  - Binning
  - Gridding (always in a spatial context)

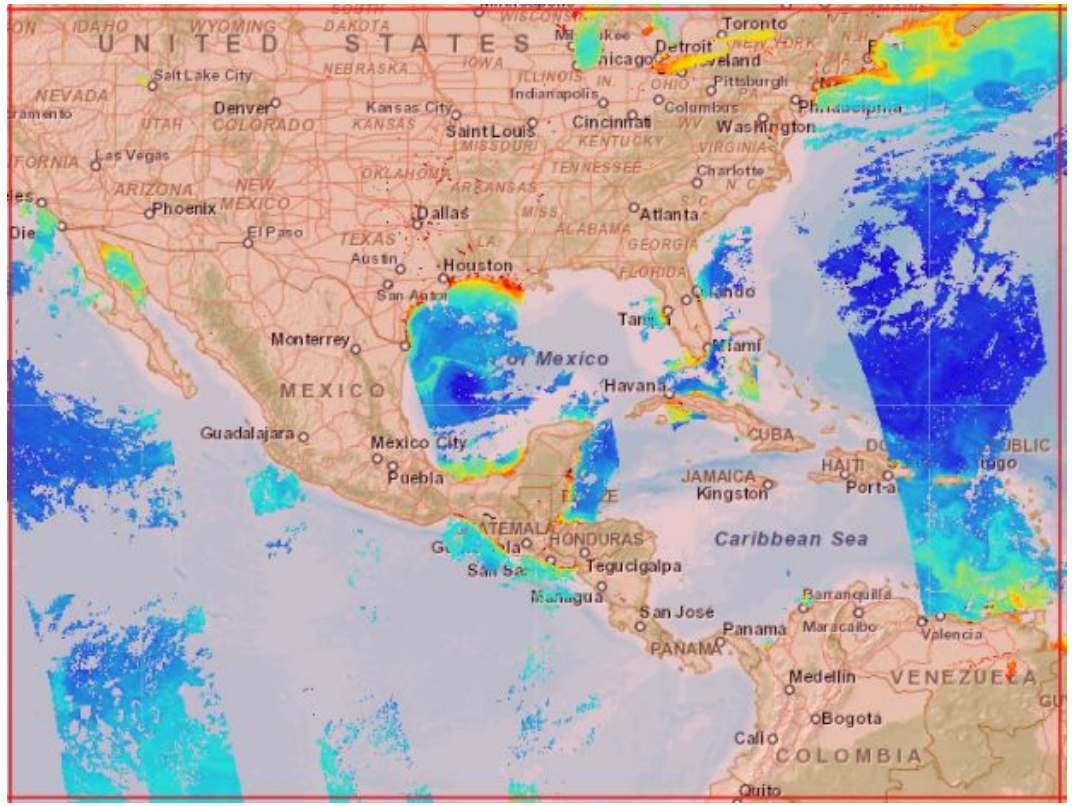


Resolutions from various chlorophyll-a products

Binning (Spatial / Temporal)

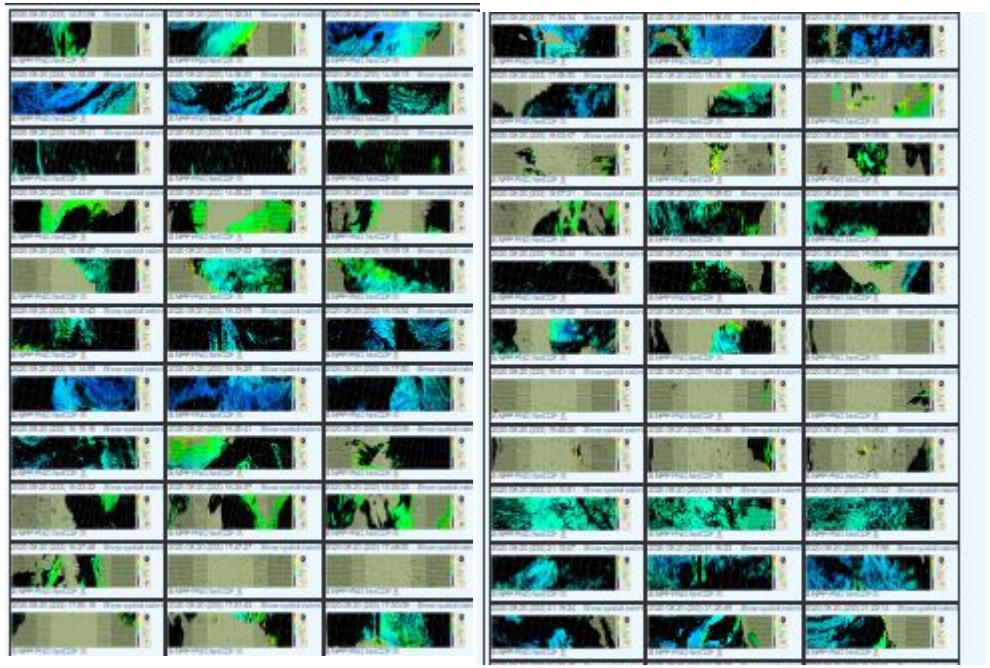


One day of granules used for CoastWatch Sector of chlorophyll-a from VIIRS

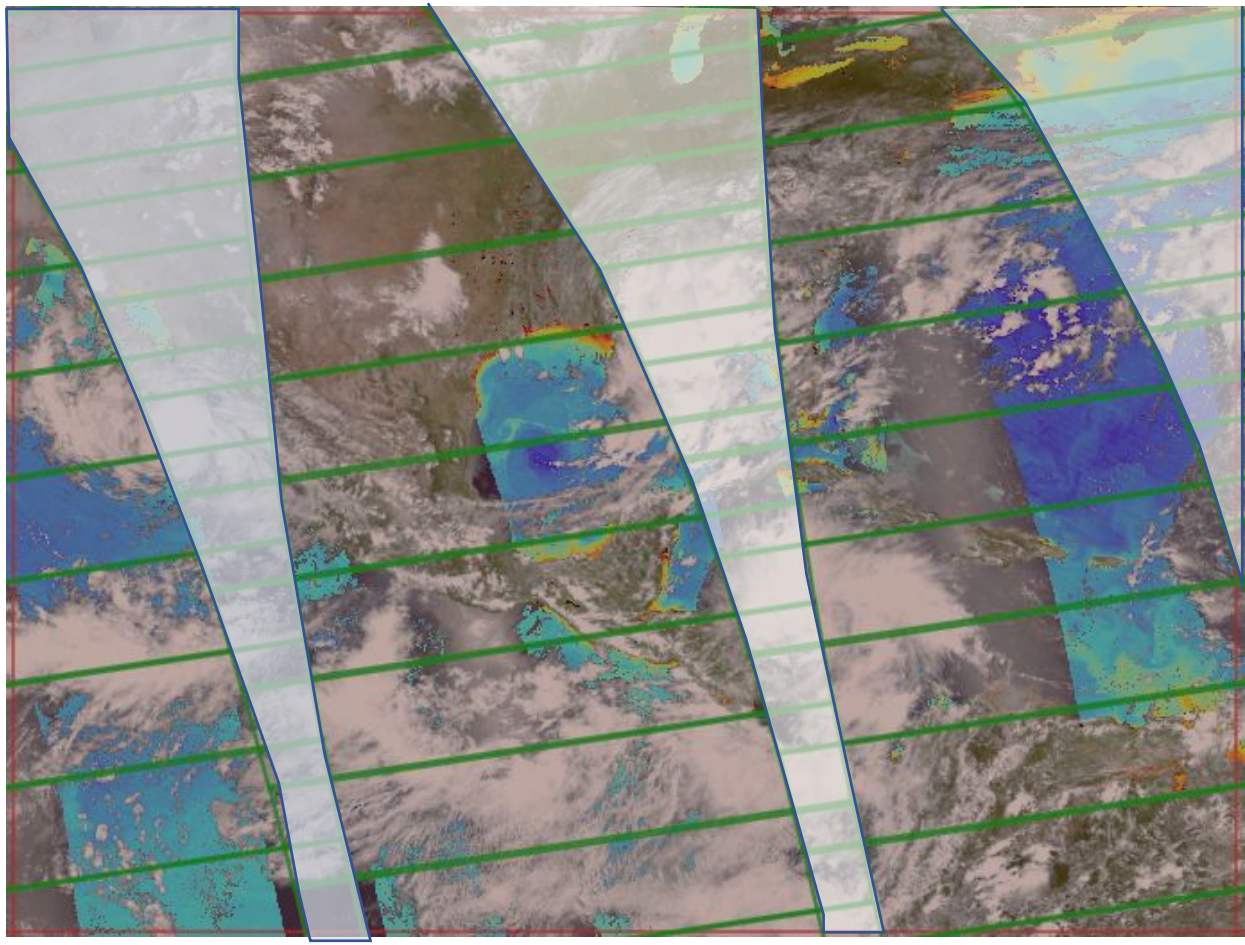


One day coverage for CoastWatch ‘Sector’

Binning: Overlapping Data



One day coverage for CoastWatch Sector of chlorophyll-a from VIIRS

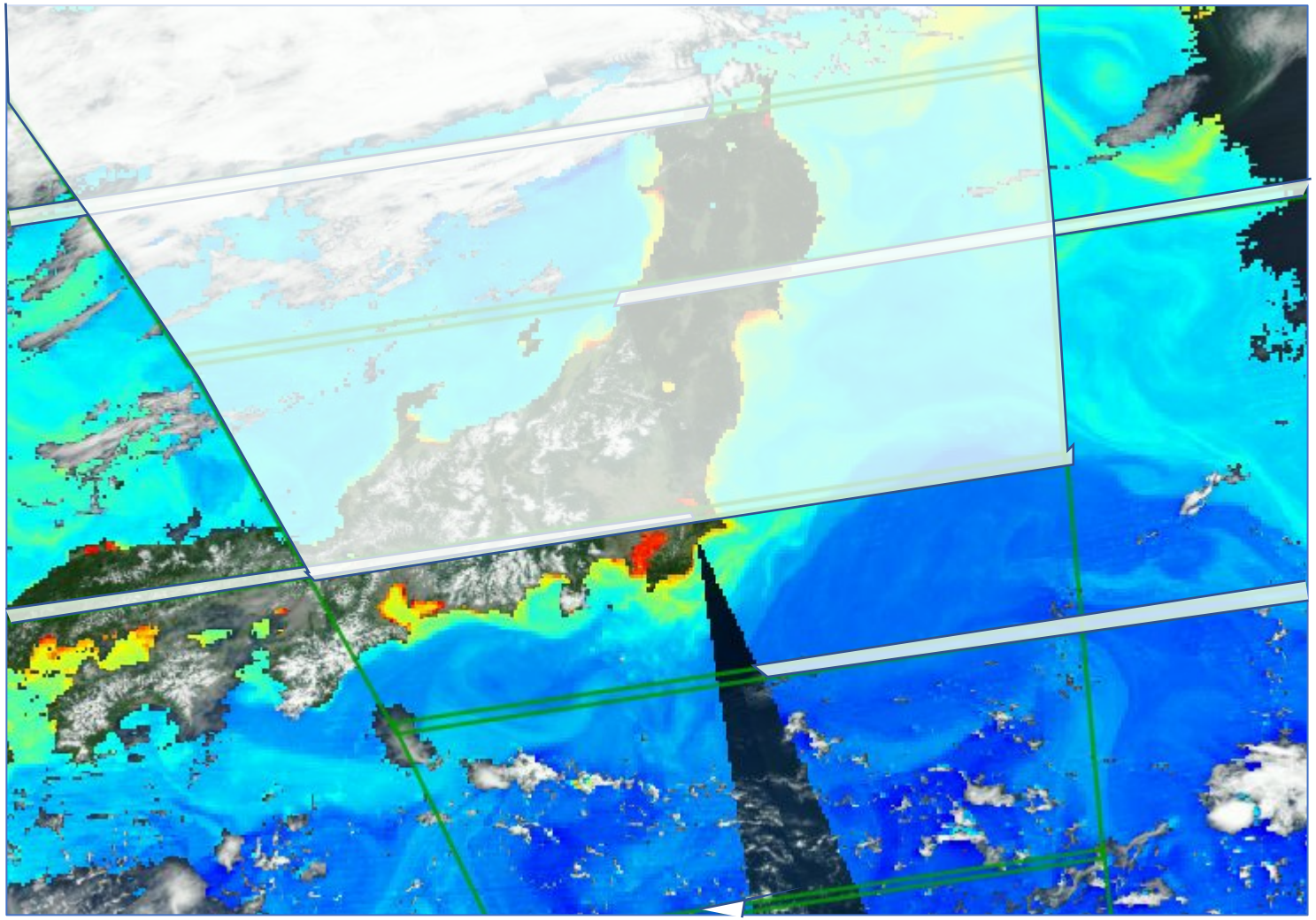


One day coverage for CoastWatch Sector of chlorophyll-a from VIIRS

Binning / Gridding

- Binning may be the minimum, maximum, average, most recent, valid value, or ‘optimal’ of overlapping pixels

- Shaded area shows pixels affected for a single daily composite

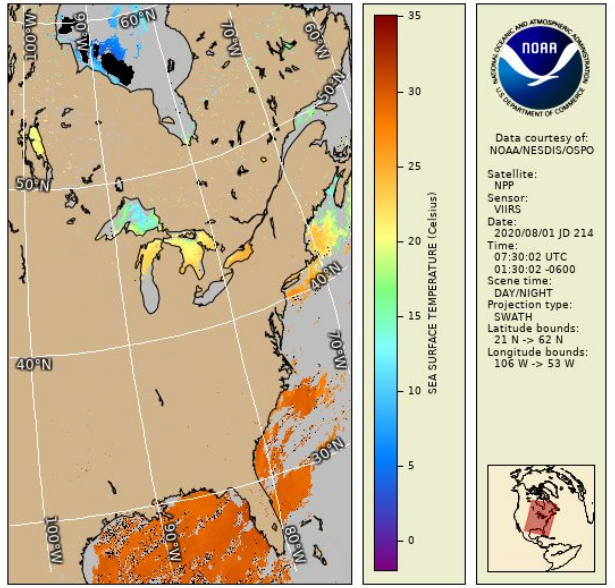


Example of overlapping VIIRS granules in shaded area

Satellite Data Product Projections

- Satellite sensor view (Swath / Level-2)
  - Irregularly/non-linearly spaced
  - May include unique structure based on sensor
  - Geolocations with respect to Ellipsoid and Datum
  - Earth rotation, platform stability, field-of-view

- Mapped (Gridded / Level-3, -4)
  - Projected Coordinate system
  - X-Y locations with respect to Ellipsoid and Datum



Summary

Projections and Coordinate Systems:

Earth is not flat or spherical, requiring complex projections for accurate satellite data representation.

Geographic (Lat/Long) and projected (2D gridded) coordinate systems play key roles in GIS applications.

Choosing a Projection:

Selection depends on project needs: conformality, area, or direction may guide your choice.

Metadata, resolution, and format considerations are critical when working with satellite data.

Handling Data:

Satellite data undergoes various binning, gridding, and reprojection processes.

Be mindful of distortion introduced through projections and re-projections.

Key Takeaway:

Understanding projection choices and their effects is essential for accurate satellite data analysis in GIS.

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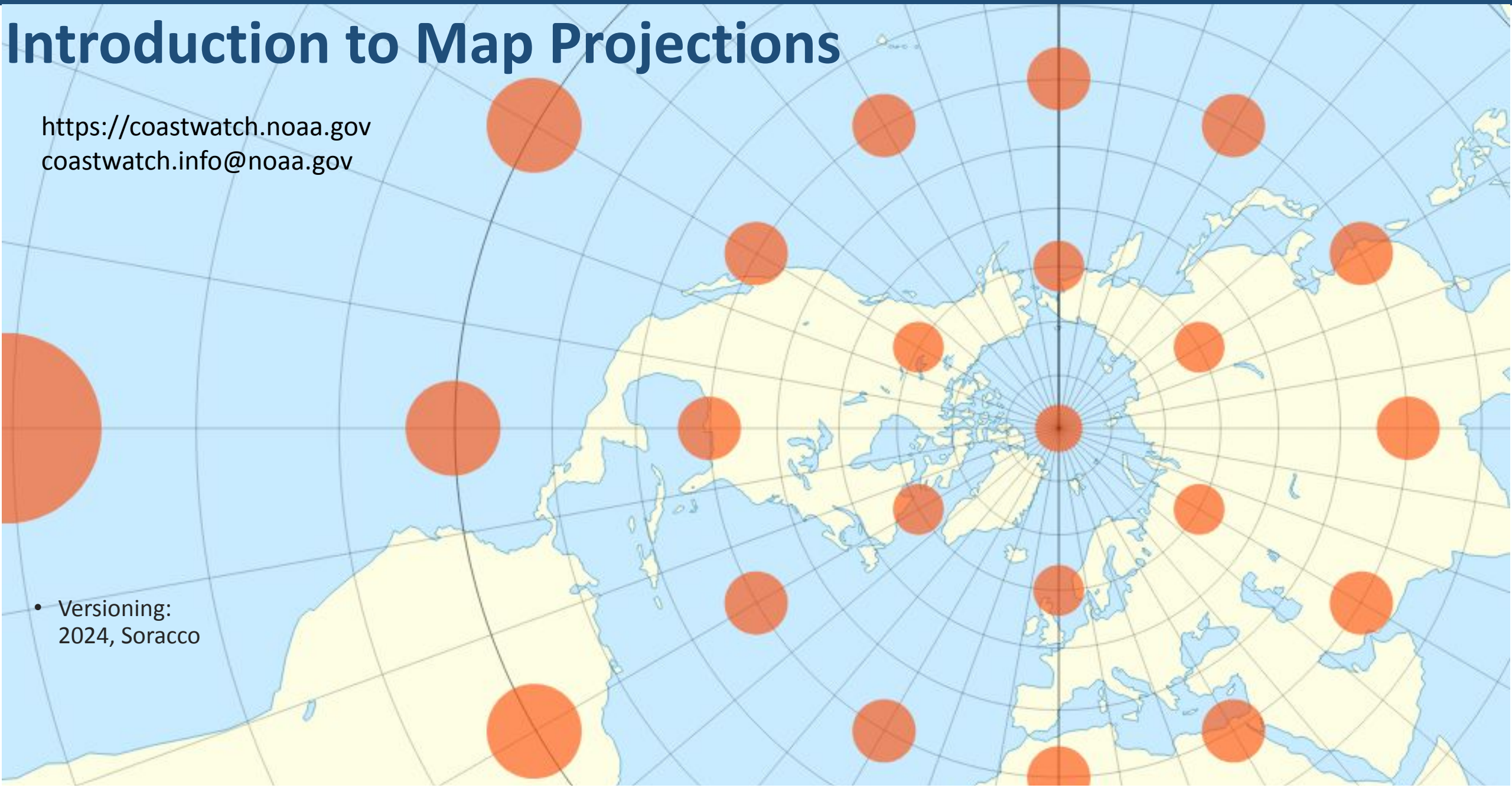

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  2024, Soracco