Coordinate Systems and Projections: An Introduction

Rob Juergens, Jianbin Duan

Projection Engine

Horizontal

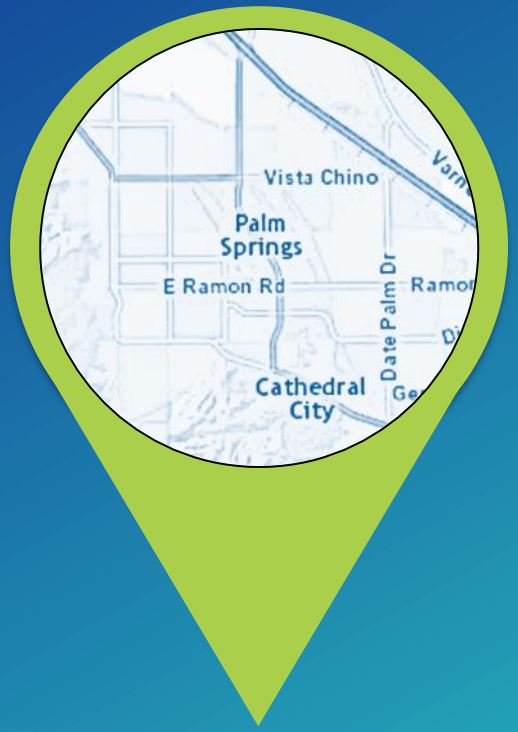
Projections

Transformations

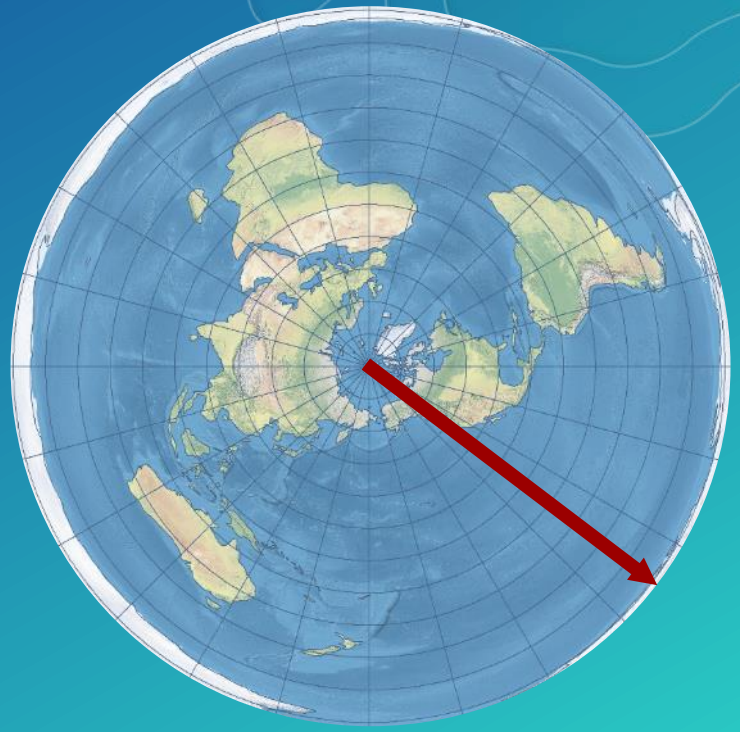
Horizontal Coordinate Systems

What does a coordinate system tell us?

Distance



Location



Direction

Two Kinds of Horizontal Coordinate Systems

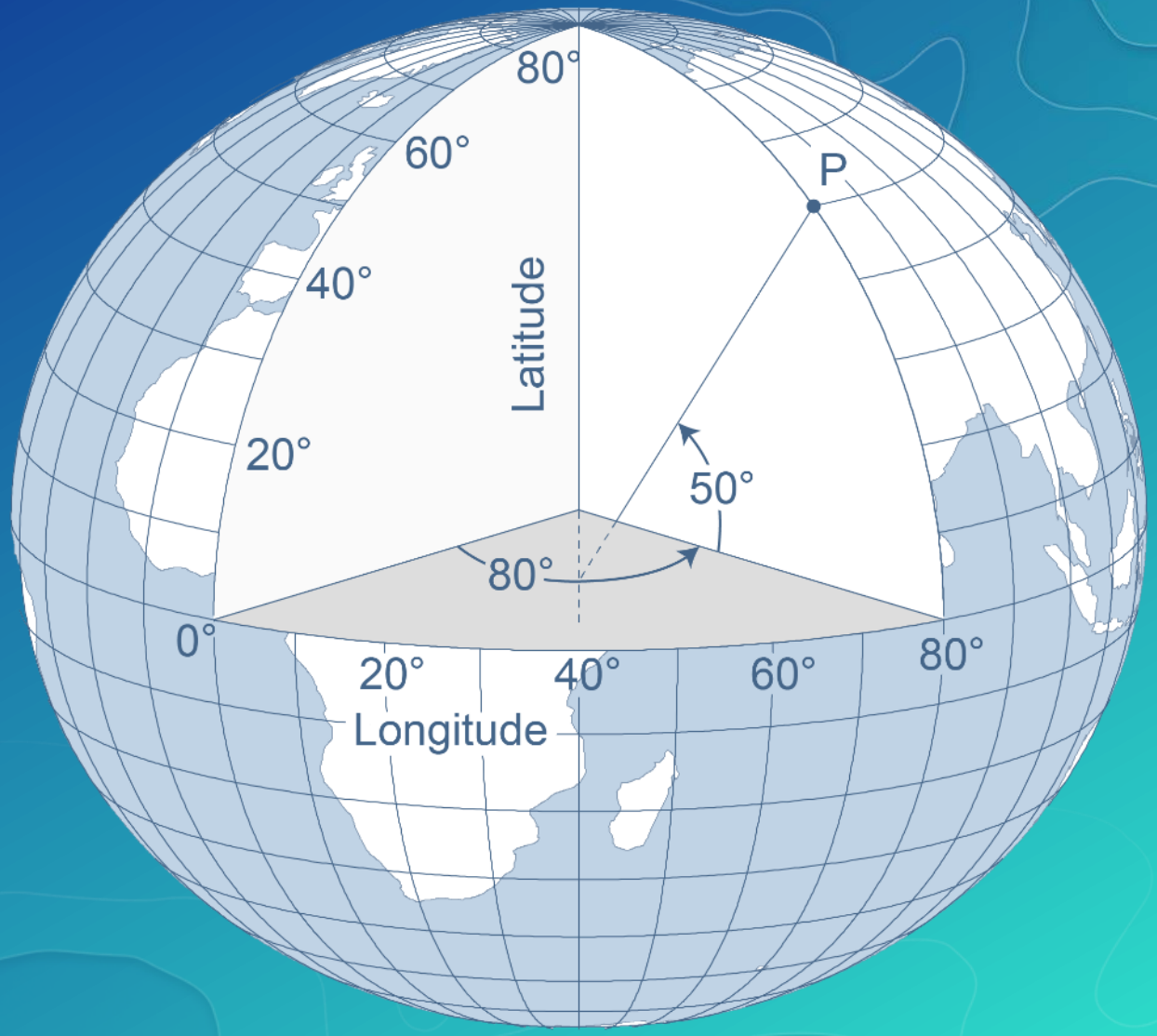
Geographic coordinate system

Projected coordinate system

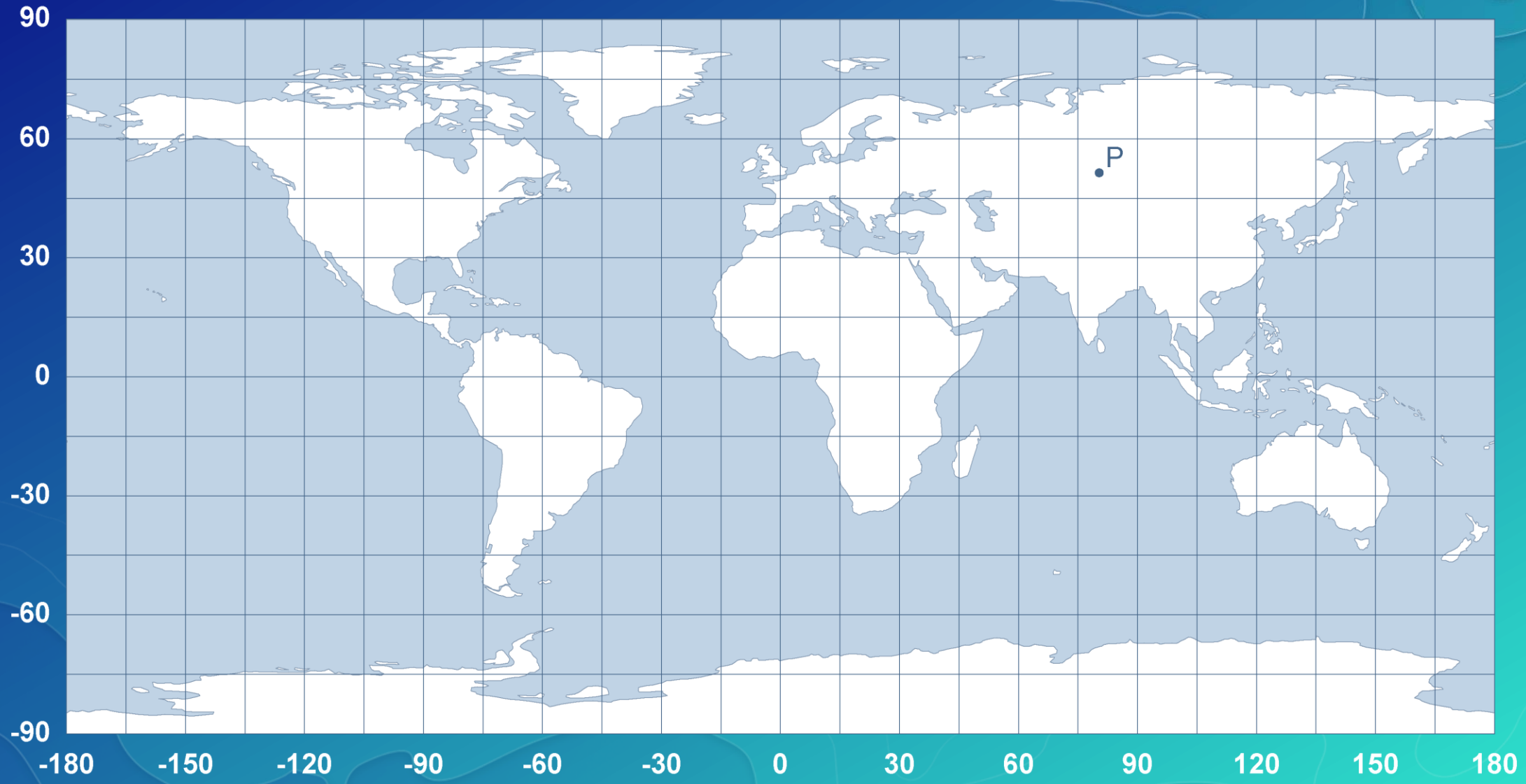
Geographic Coordinate System (GCS)

- 3D spherical surface

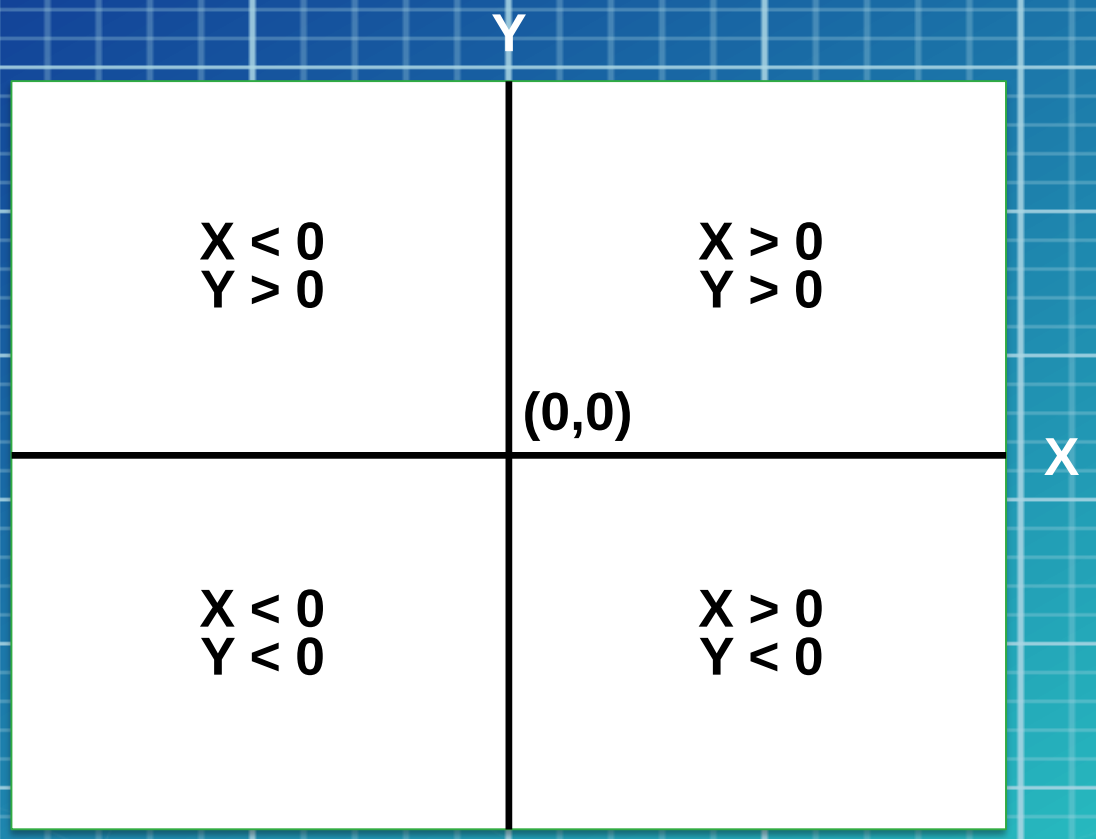
- Point P has:
  - Longitude – 80º E
  - Latitude – 50º N



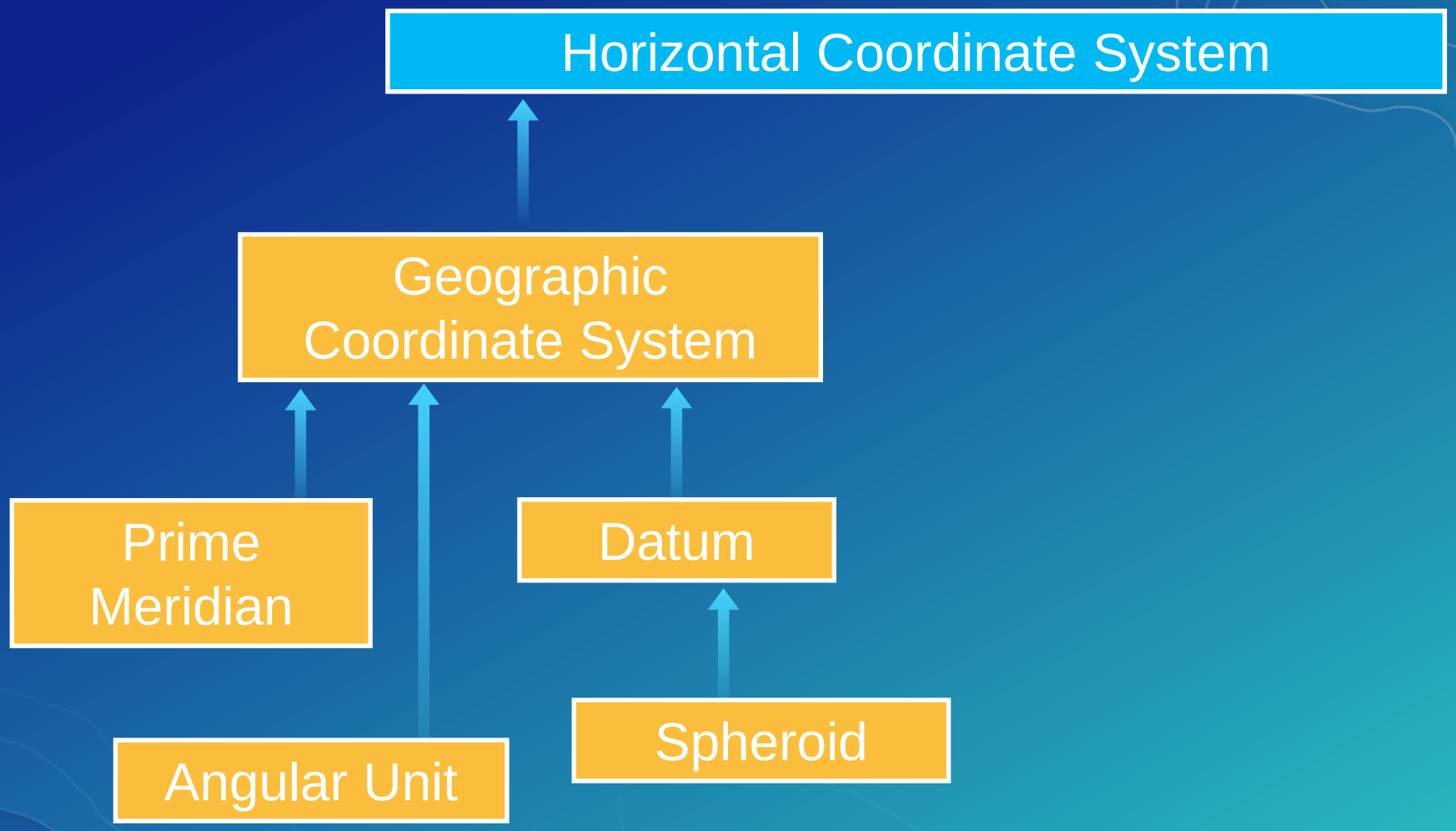
Geographic Coordinate System (GCS)

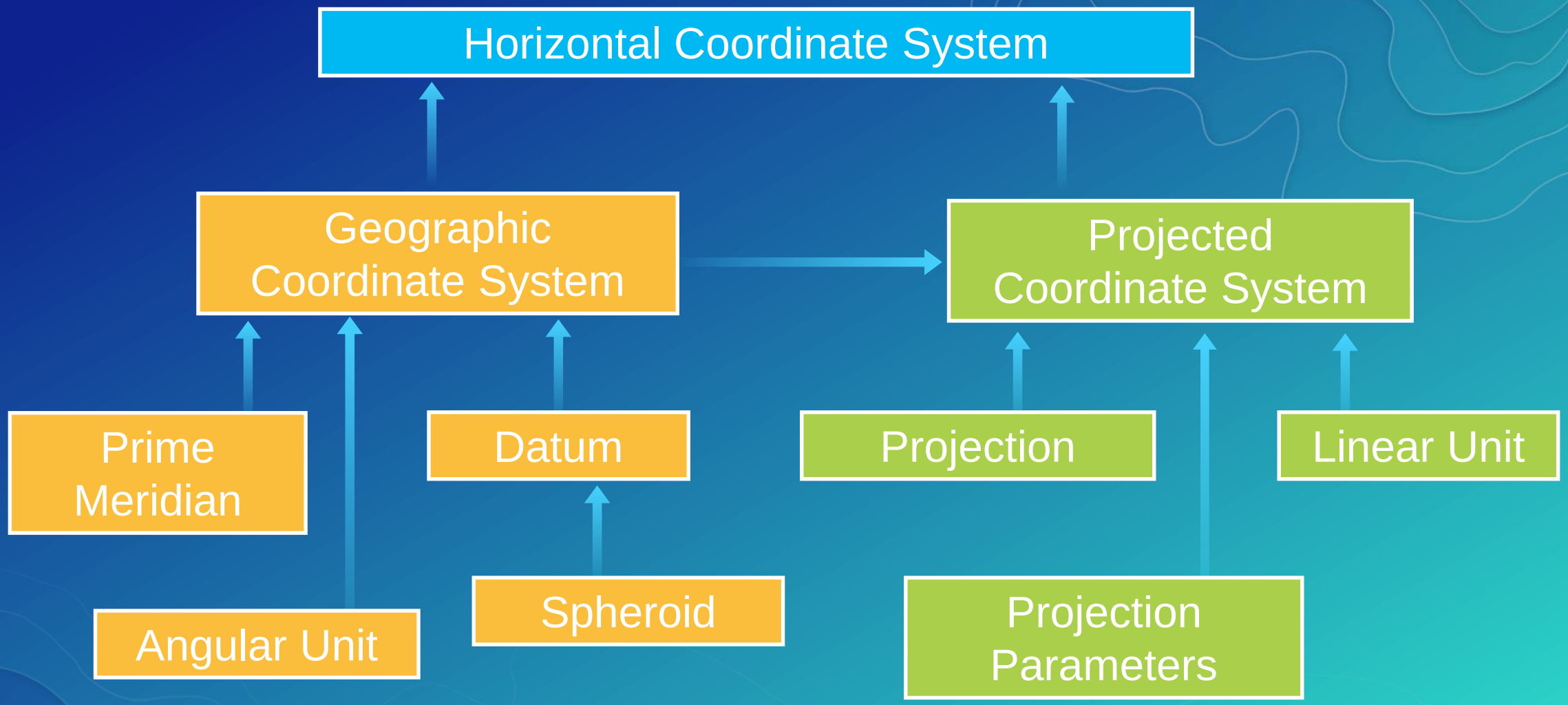


Projected Coordinate System (PCS)



Horizontal Coordinate System


Horizontal Coordinate System
Geographic Coordinate System
Prime Meridian
Angular Unit
Datum
Spheroid


Horizontal Coordinate System
Geographic Coordinate System
Projected Coordinate System
Prime Meridian
Angular Unit
Datum
Spheroid
Projection
Projection Parameters
Linear Unit

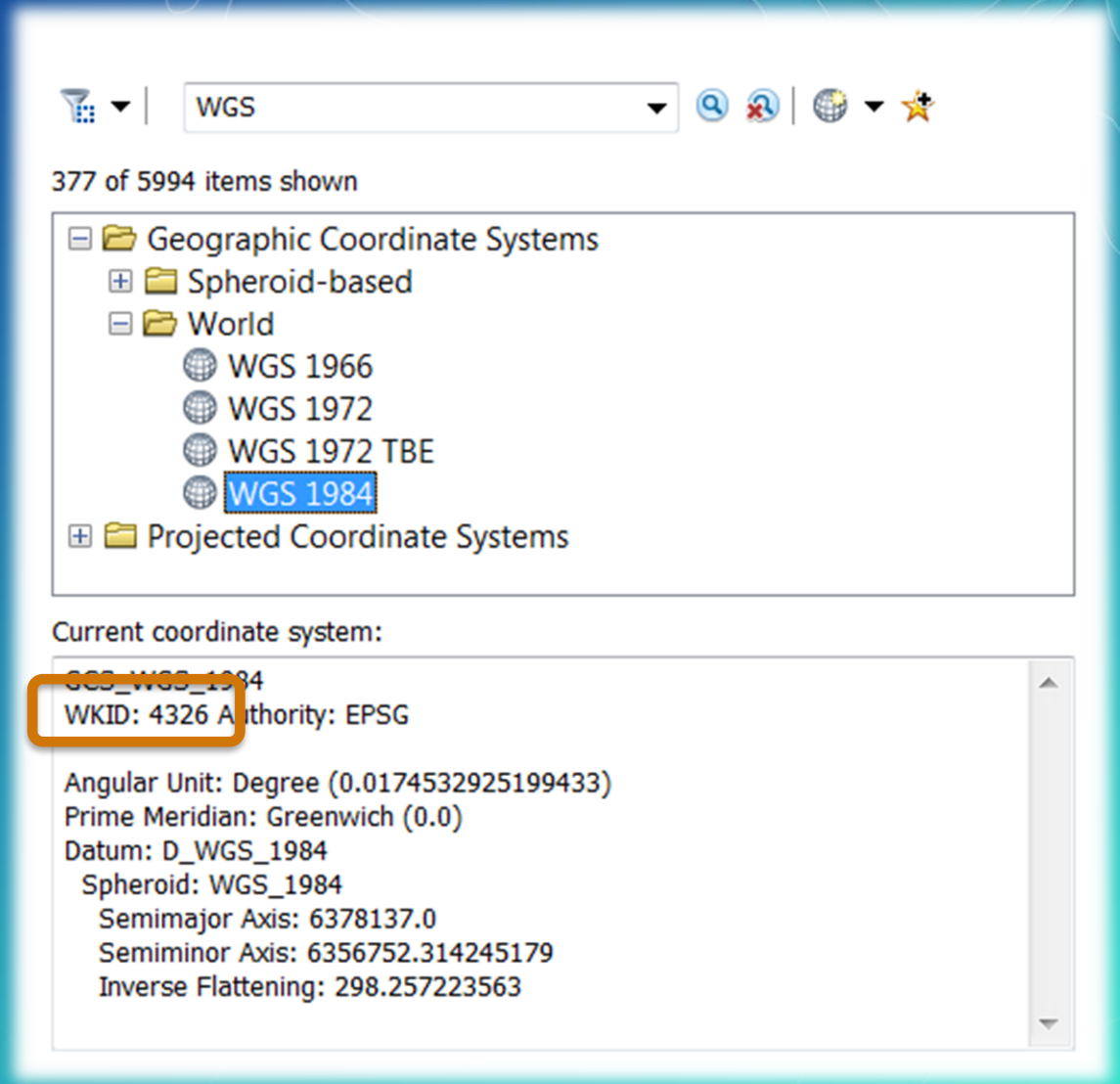
Two Ways to Specify a Coordinate System

Well-known ID

Well-known text

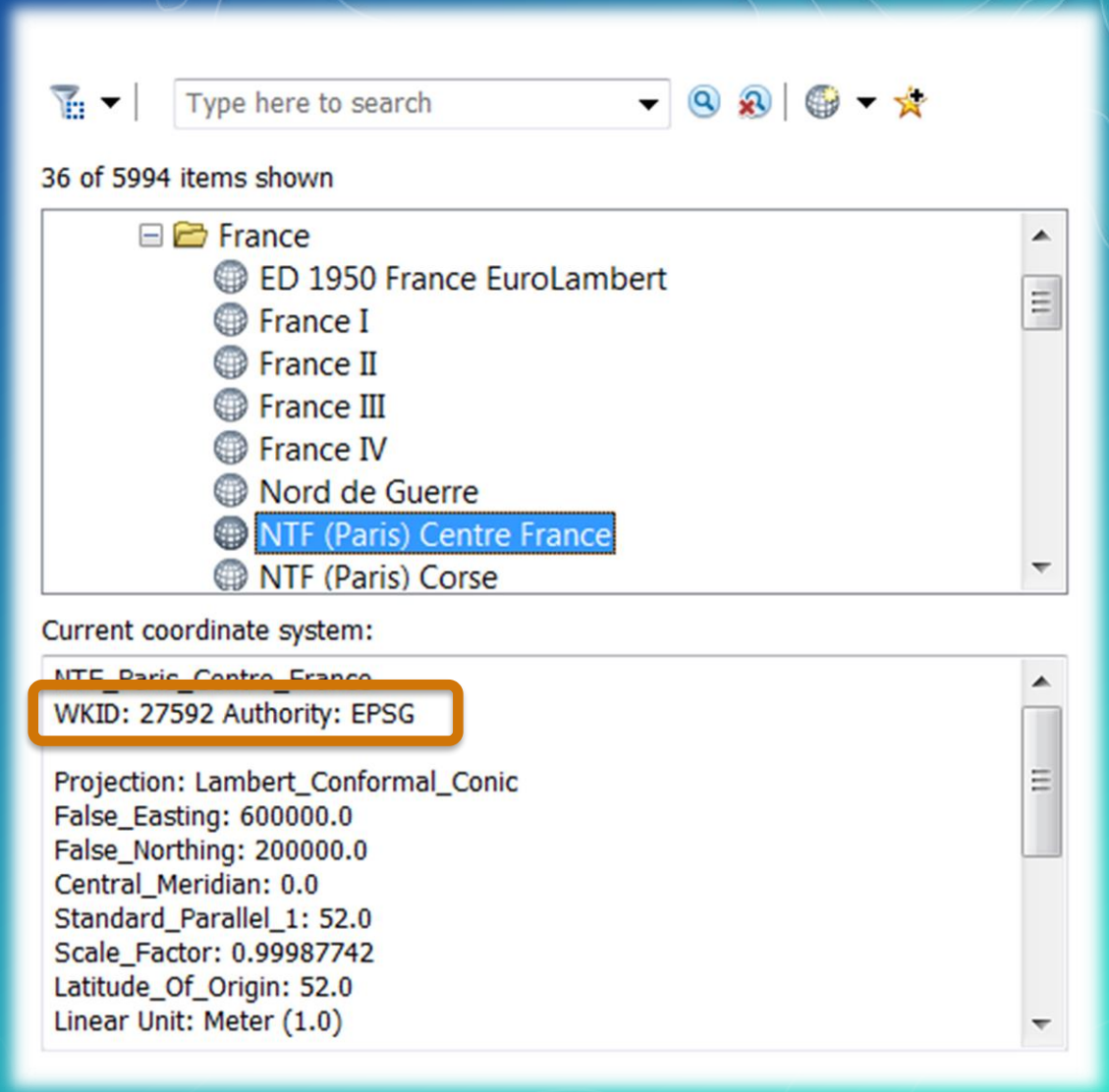
Well-Known ID (WKID)

- All predefined coordinate systems have a WKID



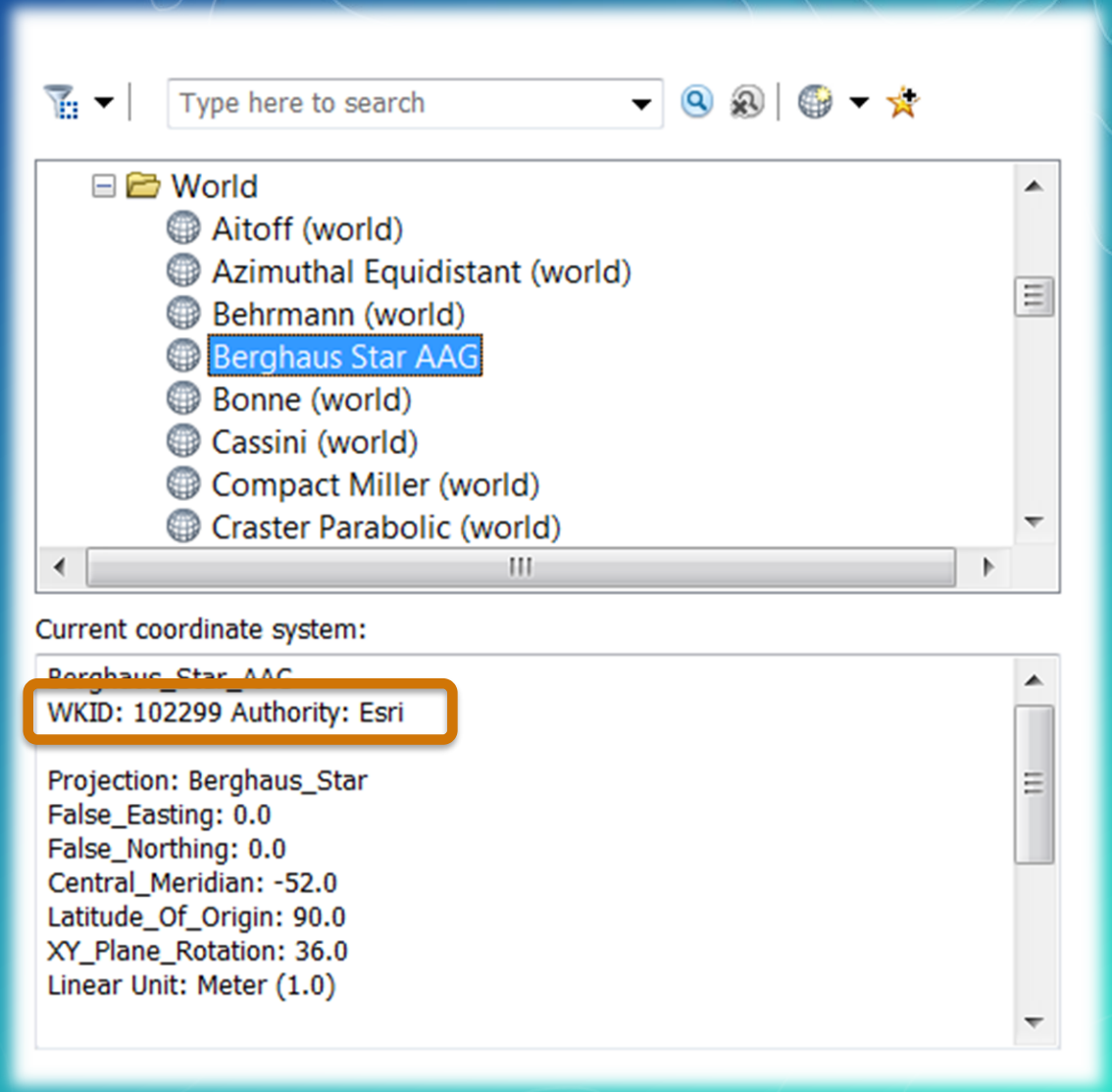
Well-Known ID (WKID)

- **WKID ≤ 32767: EPSG**
  - **EPSG Geodetic Parameter Dataset**
  - **http://www.epsg-registry.org/**



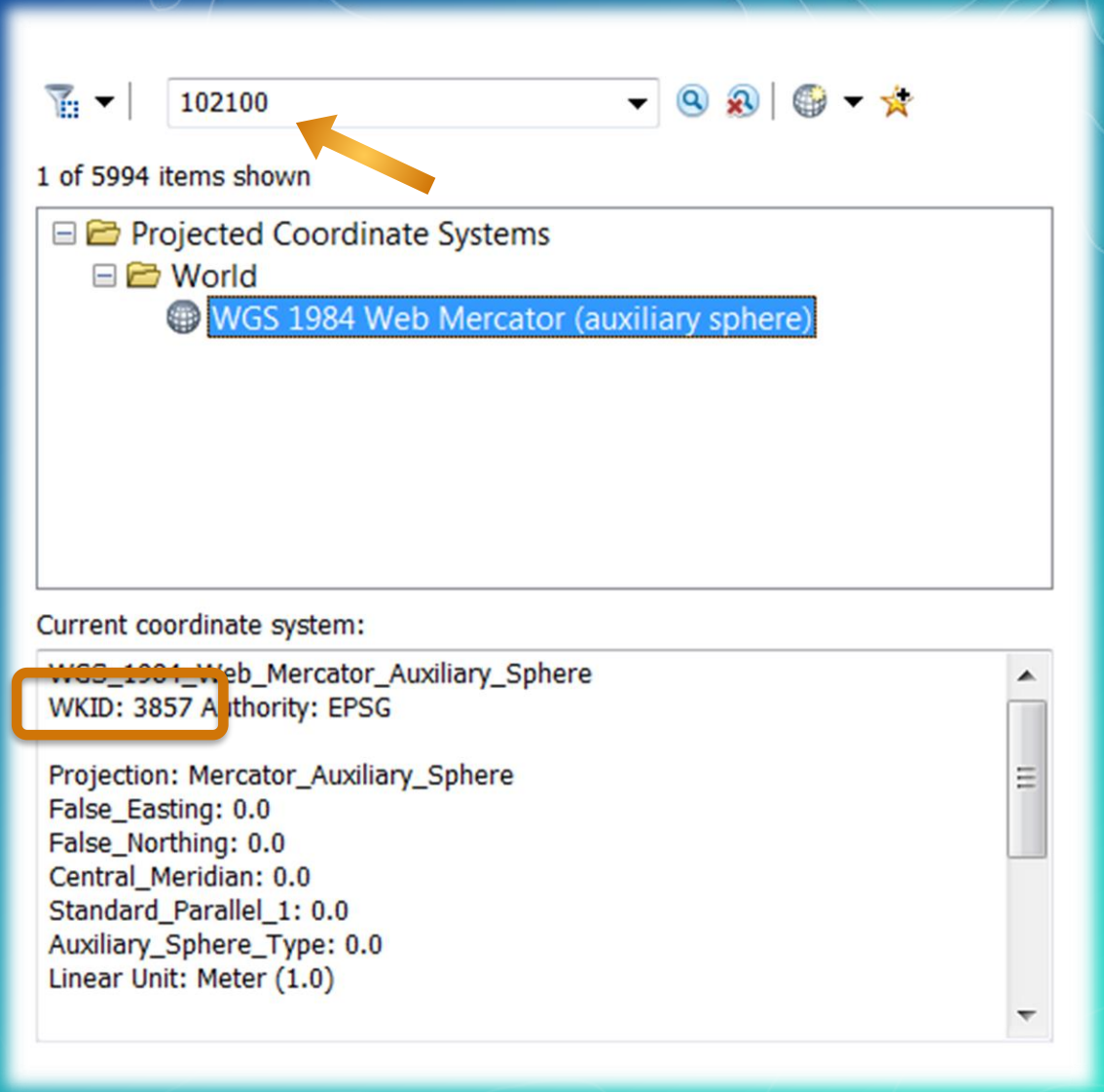
Well-Known ID (WKID)

- WKID ≤ 32767: EPSG
  - EPSG Geodetic Parameter Dataset
  - http://www.epsg-registry.org/
- WKID > 32767: Esri



Well-Known ID (WKID)

- WKID ≤ 32767: EPSG
  - EPSG Geodetic Parameter Dataset
  - http://www.epsg-registry.org/
- WKID > 32767: Esri
- Any WKID may change



Well-Known Text (WKT)

```
GEOGCS["GCS_ETRS_1989",
    DATUM["D_ETRS_1989",
        SPHEROID["GRS_1980",6378137.0,298.257222101]],
    PRIMEM["Greenwich",0.0],
    UNIT["Degree",0.0174532925199433]]
```

Geographic coordinate system

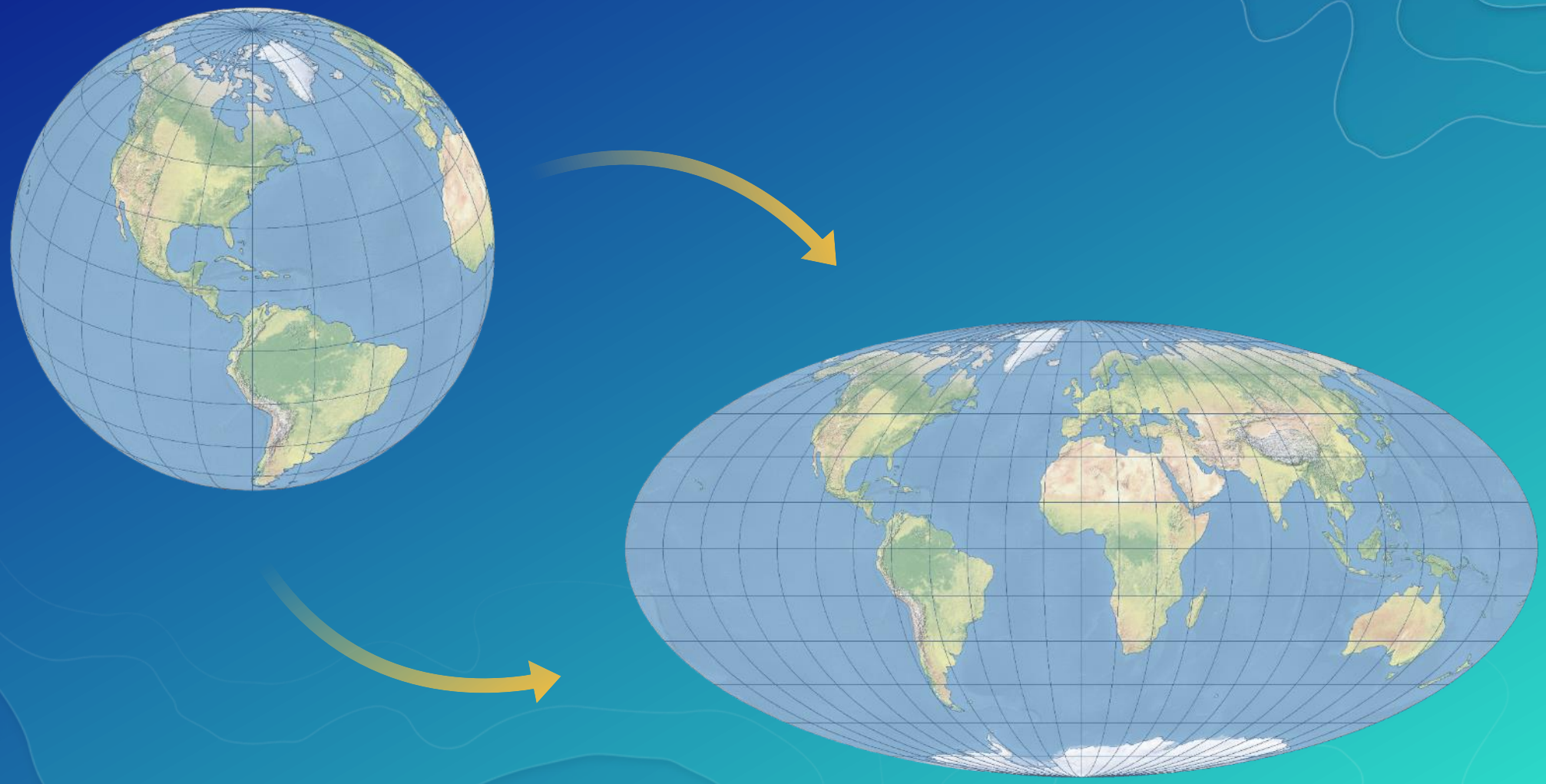
Well-Known Text (WKT)

```
PROJCS["ETRS_1989_UTM_Zone_32N",
  GEOGCS["GCS_ETRS_1989",
    DATUM["D_ETRS_1989",
        SPHEROID["GRS_1980",6378137.0,298.257222101]],
    PRIMEM["Greenwich",0.0],
    UNIT["Degree",0.0174532925199433]],
  PROJECTION["Transverse_Mercator"],
  PARAMETER["False_Easting",500000.0],
  PARAMETER["False_Northing",0.0],
  PARAMETER["Central_Meridian",9.0],
  PARAMETER["Scale_Factor",0.9996],
  PARAMETER["Latitude_Of_Origin",0.0],
  UNIT["Meter",1.0]]
```

Projected coordinate system

Projections

Projecting to a Different Coordinate System



Our Map Projections

Aitoff
Albers
Azimuthal equidistant
Behrmann
Berghaus Star
Bonne
Cassini
Compact Miller
Craster Parabolic
Cube
Cylindrical equal-area
Double stereographic
Eckert Greifendorff
Eckert I
Eckert II
Eckert III
Eckert IV
Eckert V
Eckert VI

Equidistant conic
Equidistant cylindrical
Flat polar quartic
Fuller
Gall stereographic
Gauss Kruger
Gnomonic
Goode Homolosine
Hammer-Aitoff
Hotine oblique Mercator
IGAC Plano Cartesiano
Krovak
Laborde oblique Mercator
Lambert azimuthal equal-area
Lambert conformal conic
Local
Loximuthal
Mercator
Miller cylindrical

Mollweide
Natural Earth
Natural Earth II
New Zealand map grid
Ney modified conic
Orthographic
Patterson
Plate Carree
Polyconic
Quartic authalic
Rectified skew orthomorphic
Robinson
Sinusoidal
Stereographic
Times
Transverse cylindrical equal-area
Transverse Mercator
Two point equidistant
Van der Grinten I

Vertical near side perspective
Wagner IV
Wagner V
Wagner VII
Winkel I
Winkel II
Winkel Tripel

Azimuthal equidistant auxiliary sphere
Eckert IV auxiliary sphere
Eckert VI auxiliary sphere
Equidistant cylindrical auxiliary sphere
Gnomonic auxiliary sphere
Lambert azimuthal equal-area auxiliary sphere
Mercator auxiliary sphere
Miller cylindrical auxiliary sphere
Mollweide auxiliary sphere
Orthographic auxiliary sphere
Van der Grinten I auxiliary sphere

Why are there so many map projections?

- Shape
- Area
- Direction
- Distance

Illustration by Charles Preppernau, geolographer.xyz

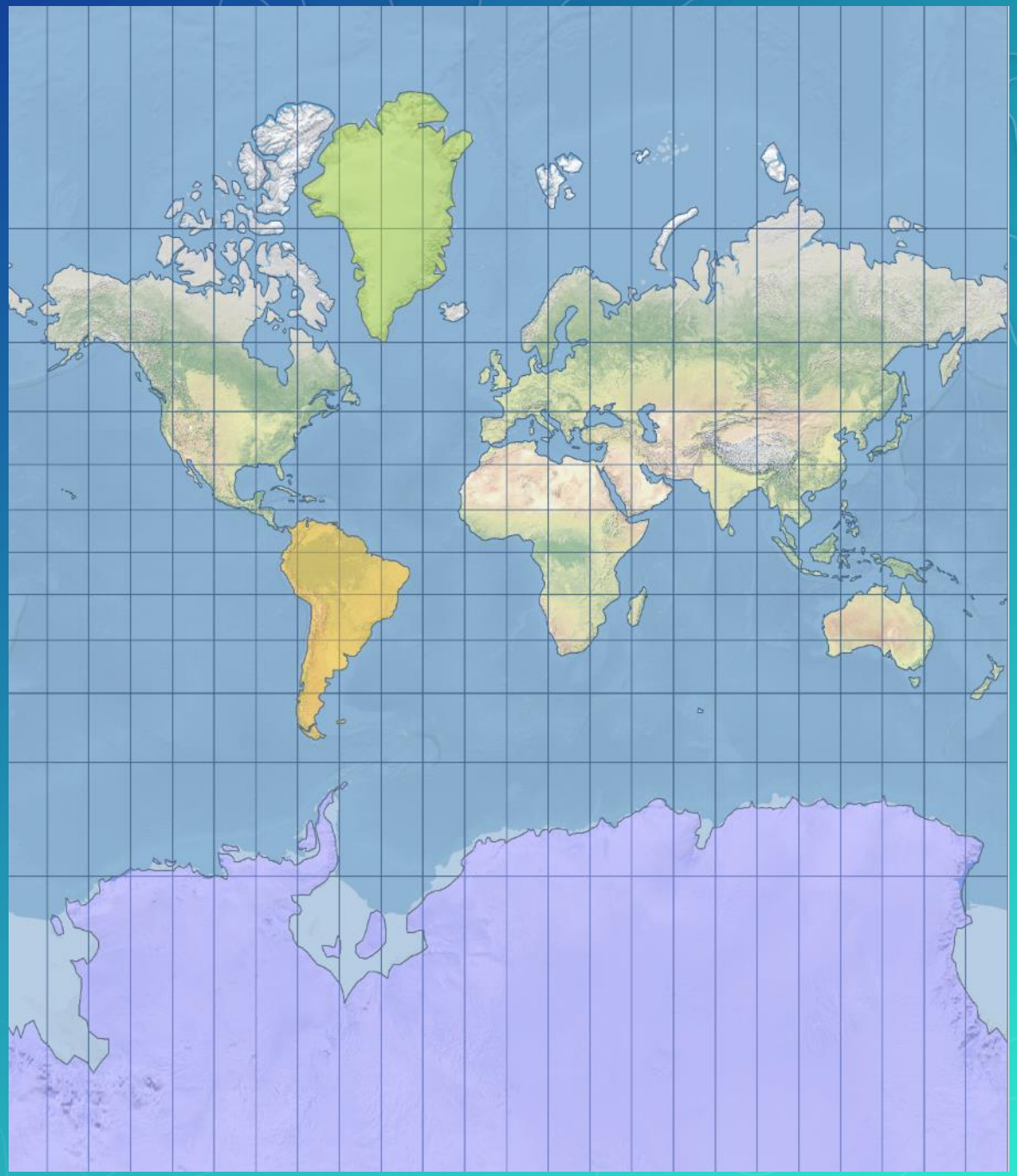
Web Mercator Projection

- Q: Which is bigger?

South America

Greenland

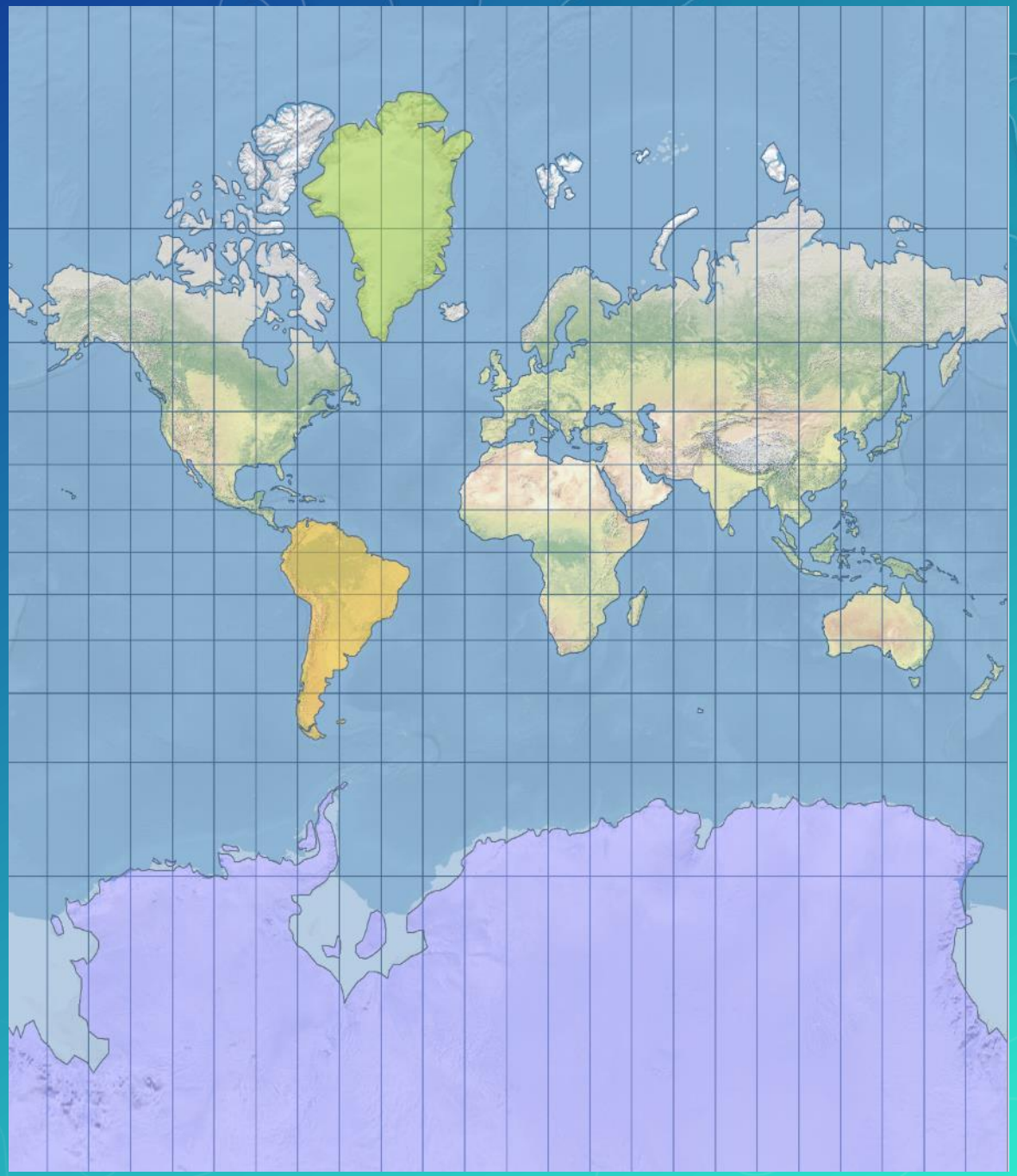
Antarctica



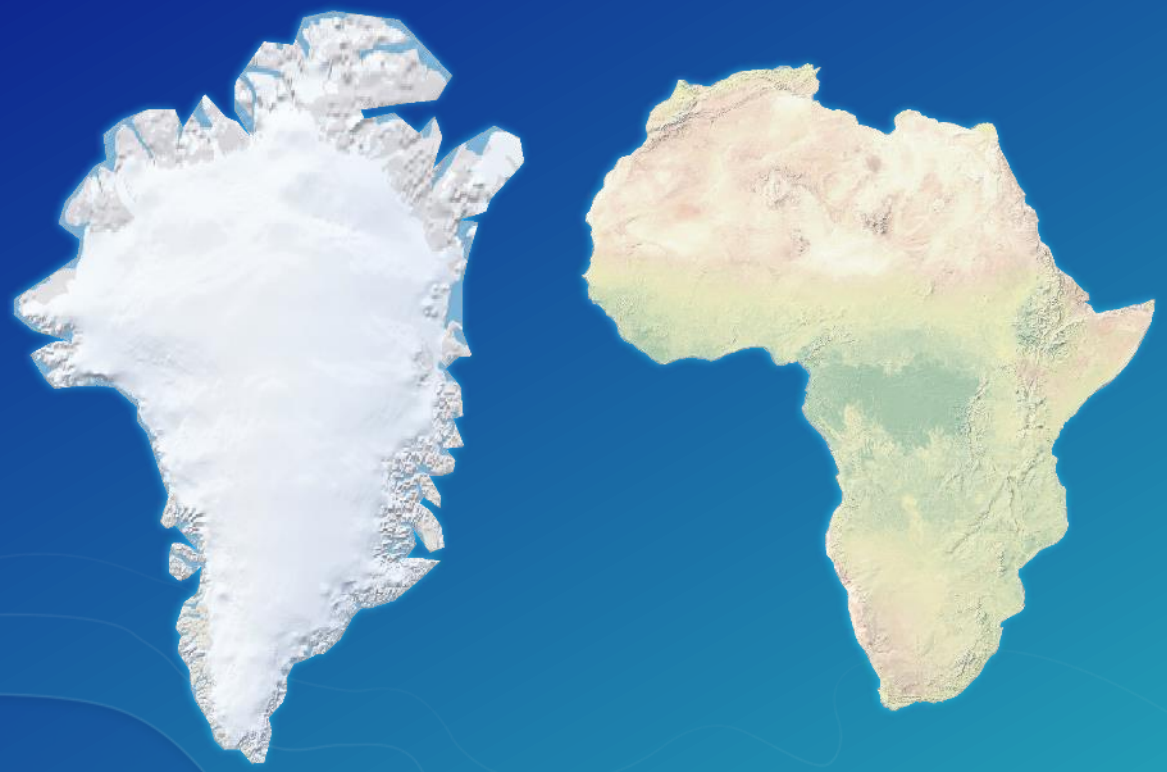
Web Mercator Projection

- Q: Which is bigger?

South America	~	17 840 000 km^2
Greenland	~	2 166 000 km^2
Antarctica	~	14 000 000 km^2



Web Mercator Projection vs. Reality



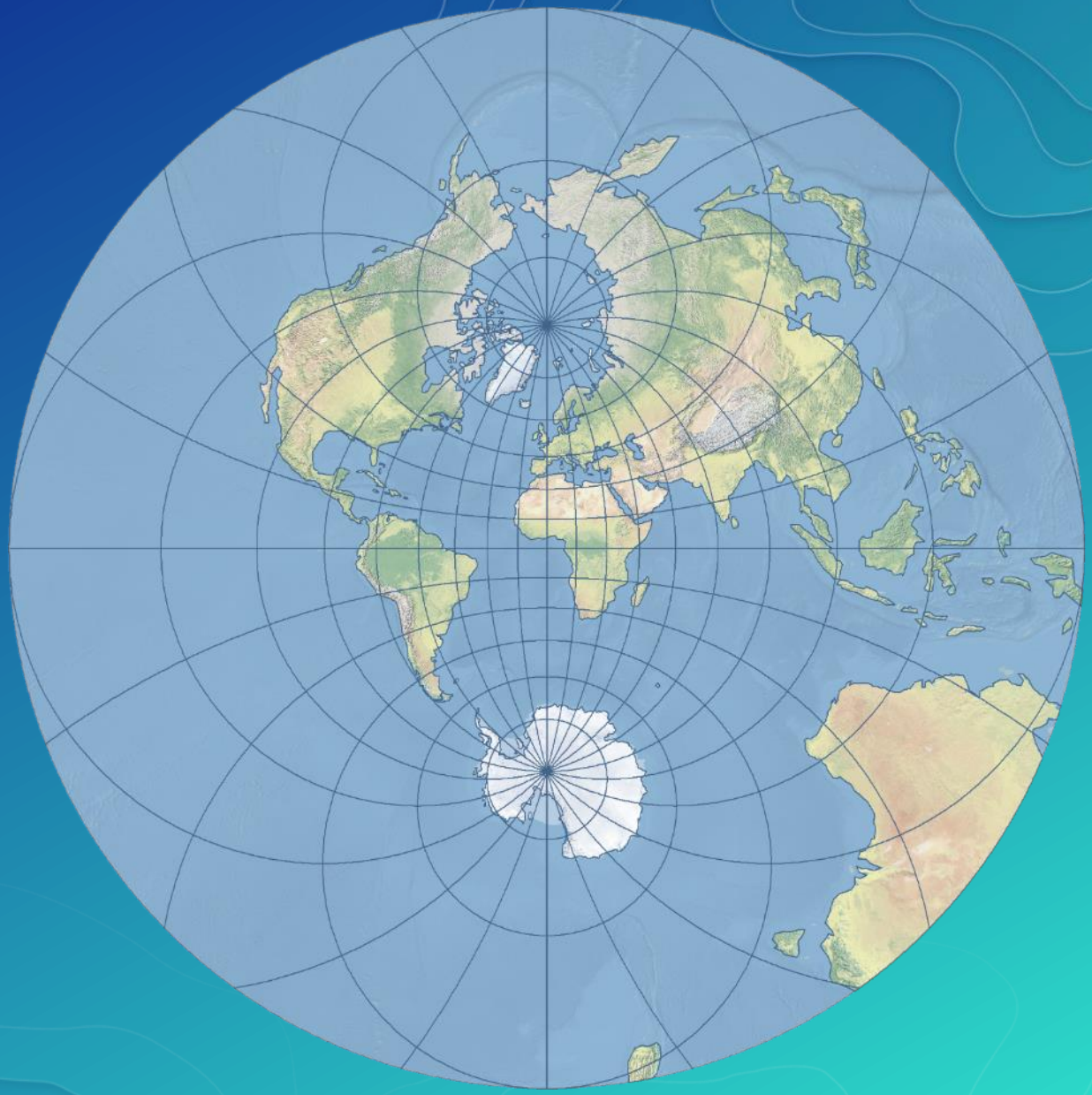
What is most important to preserve?

- Shape
- Area
- Direction
- Distance

Depends on what you are doing

Preserve Shape

- Stereographic

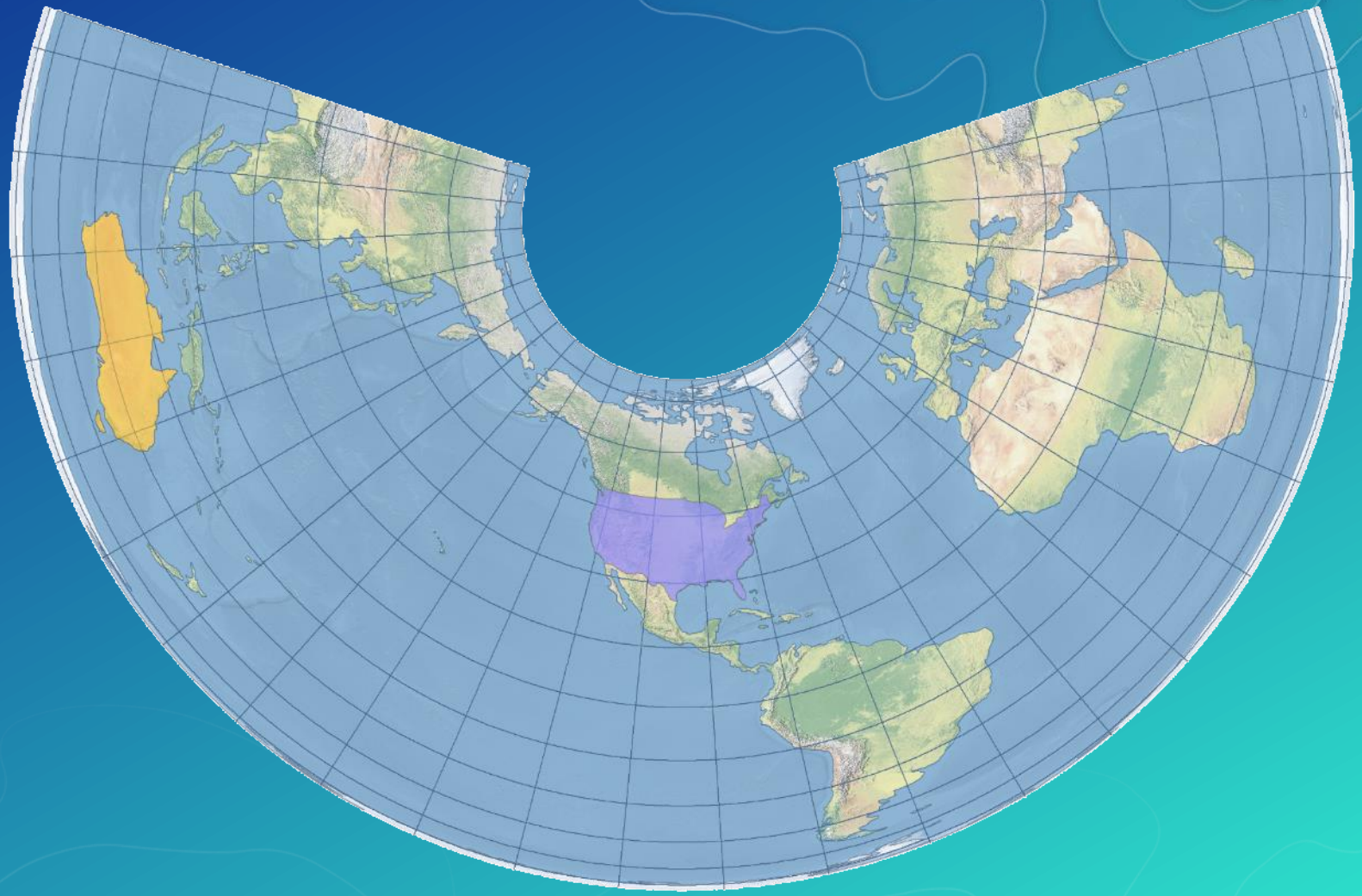


Preserve Area

- Albers equal-area conic

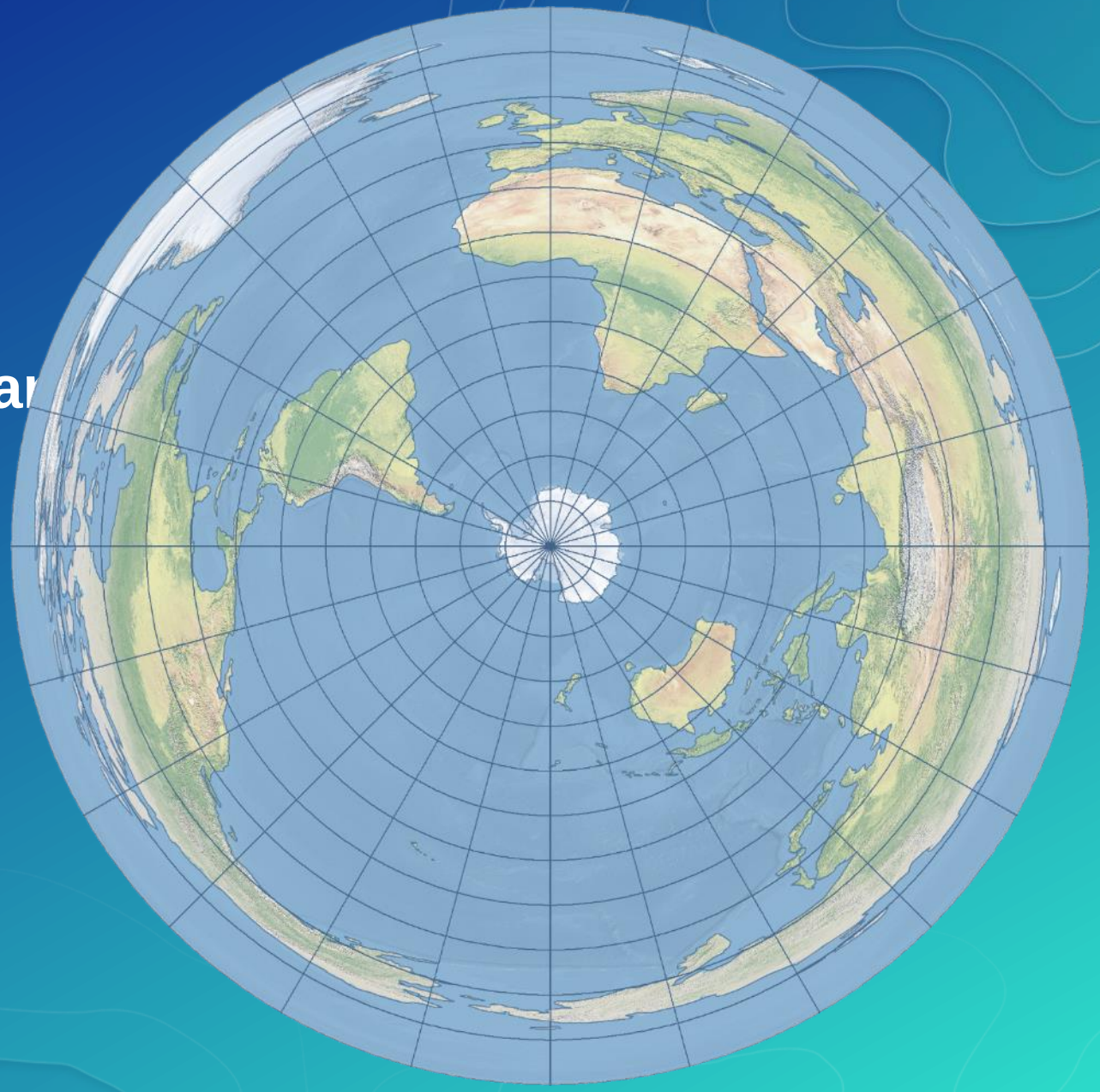
Preserve Area

- Albers equal-area conic



Preserve Direction and Distance

- Azimuthal equidistan



What is happening when we project data?

- **Case 1: Both PCSs contain the same GCS**

(x, y) PCS A1

PCS A2 (x, y)

GCS A (lon, lat) (λ, φ)

What is happening when we project data?

- **Case 1: Both PCSs contain the same GCS**

What is happening when we project data?

- **Case 1: Both PCSs contain the same GCS**

What is happening when we project data?

- **Case 2: Each PCS contains a different GCS**

(x, y) PCS A1

PCS B1 (x, y)

(lon, lat)
(λ, φ) GCS A

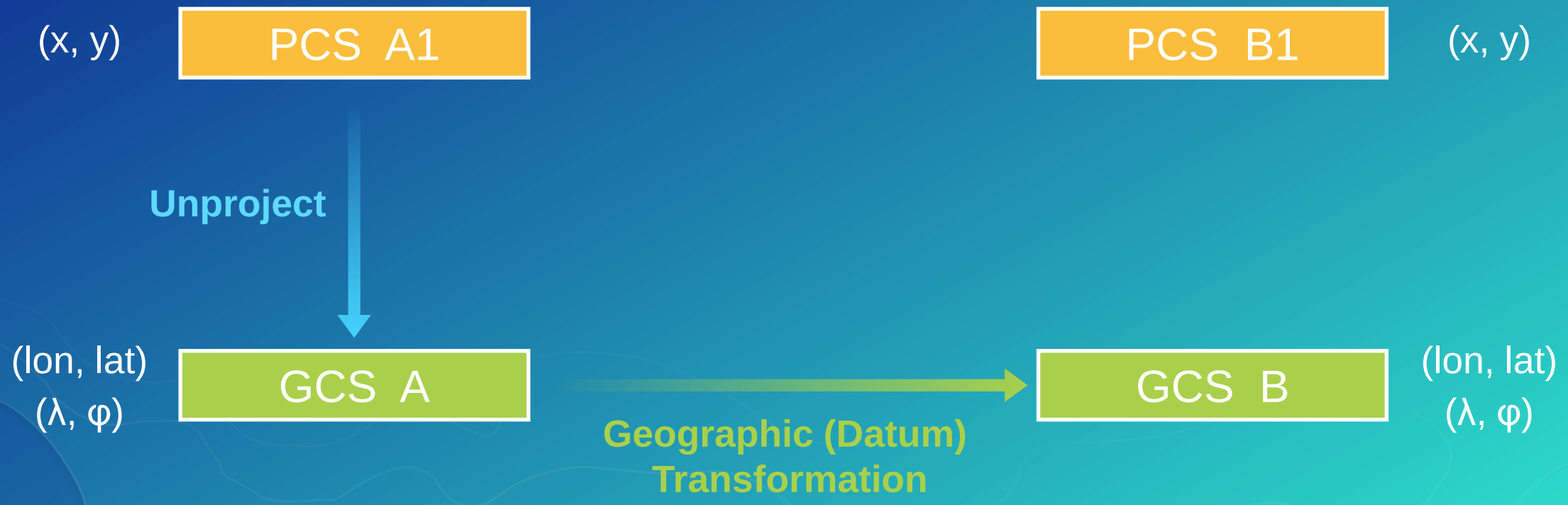
GCS B (lon, lat)
(λ, φ)

What is happening when we project data?

- **Case 2: Each PCS contains a different GCS**

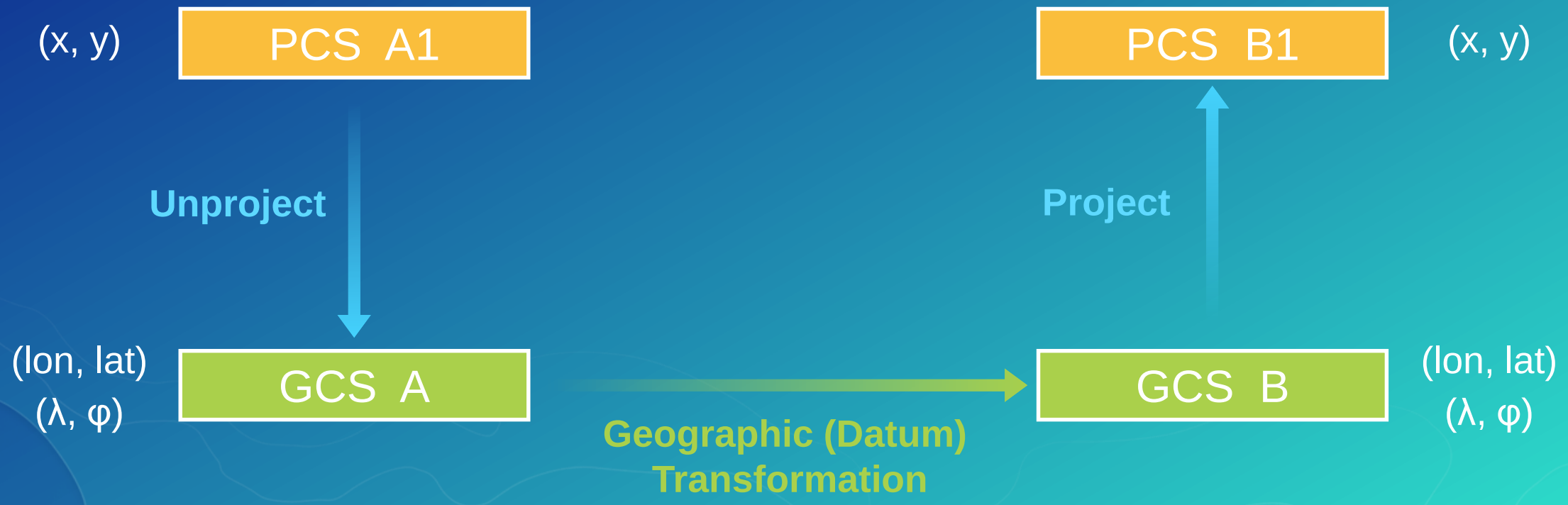
What is happening when we project data?

- **Case 2: Each PCS contains a different GCS**



What is happening when we project data?

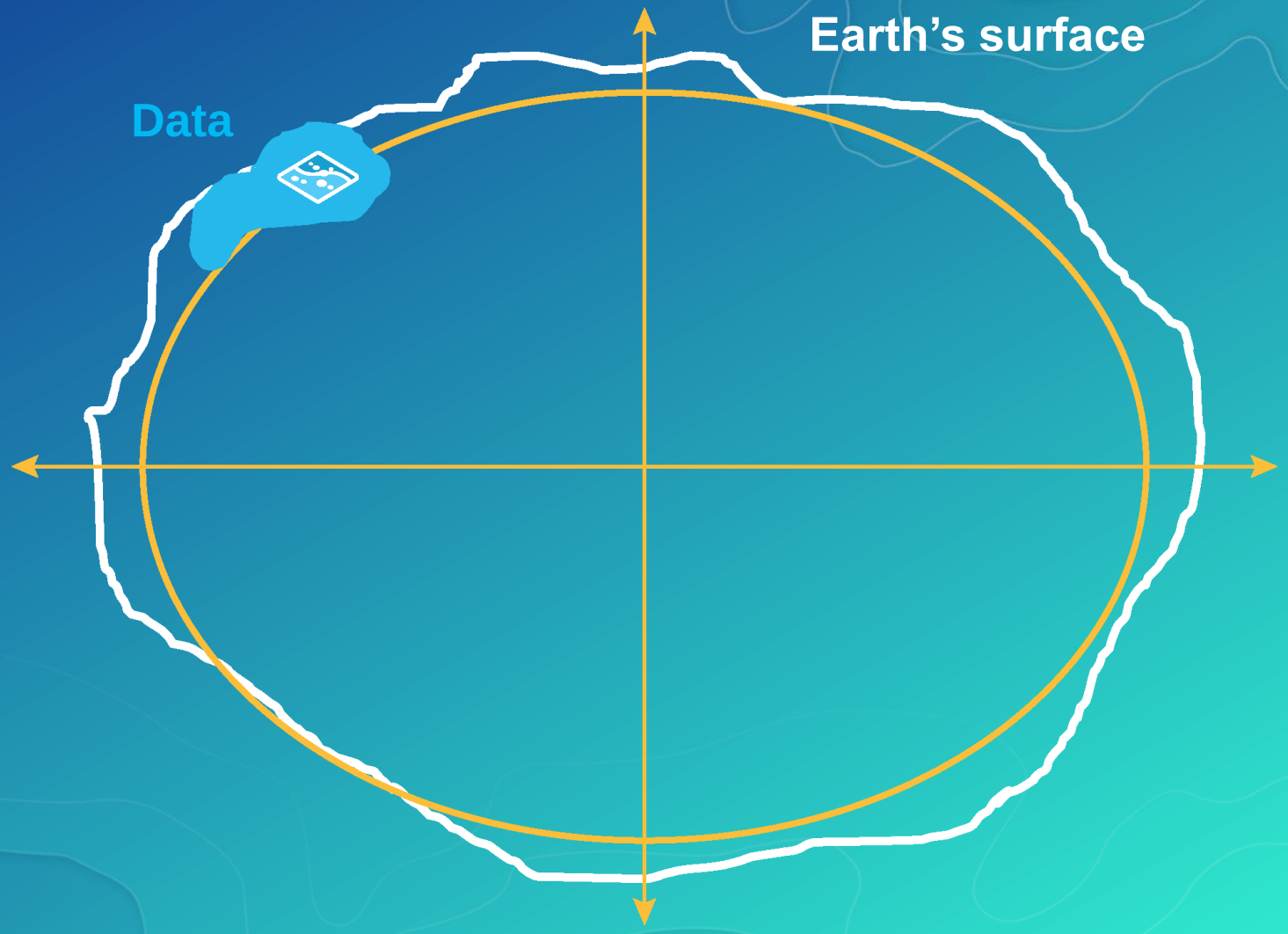
- **Case 2: Each PCS contains a different GCS**



Transformations

Transforming Means Changing Datum

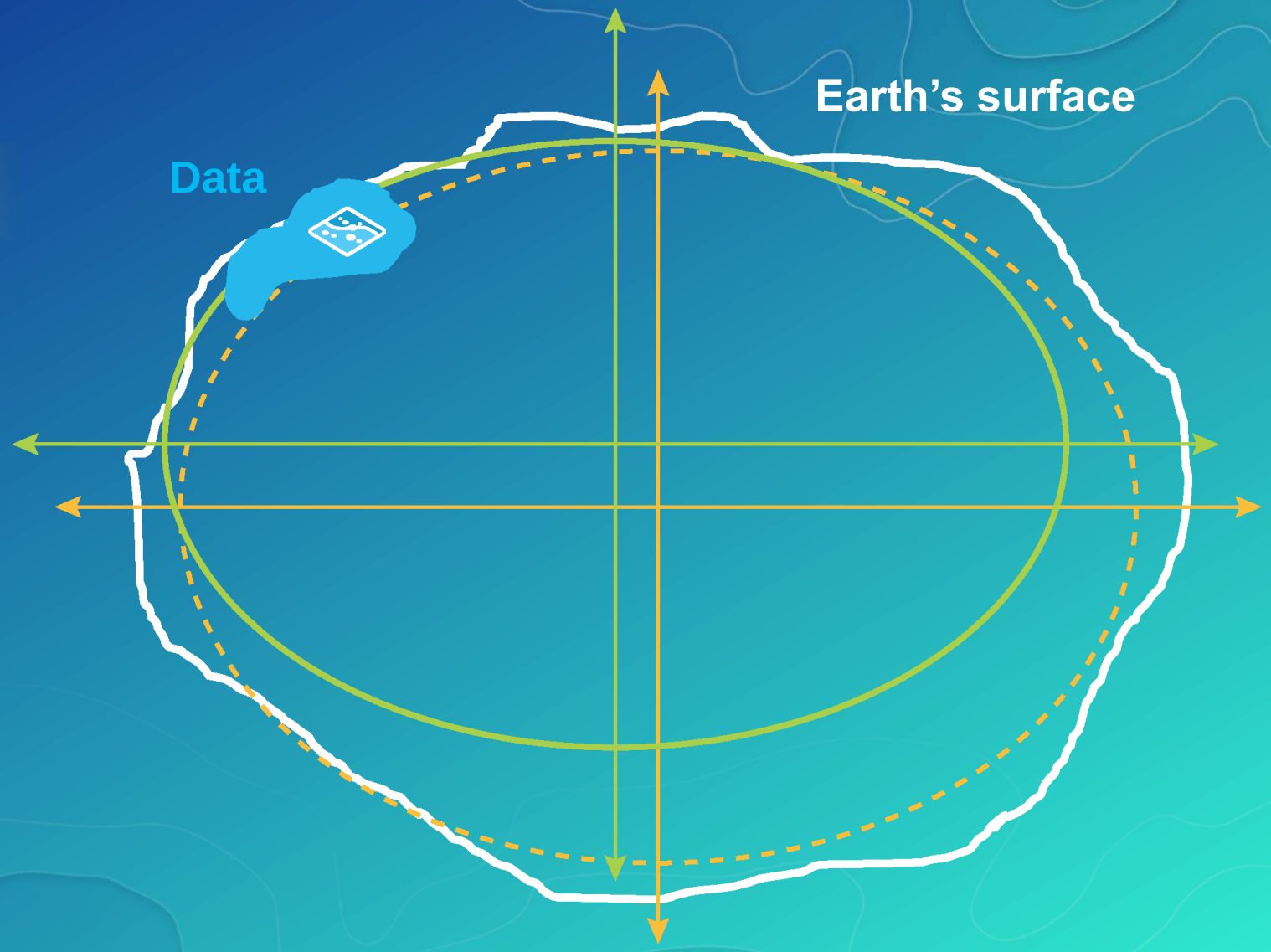
Earth-centered datum (WGS 84)



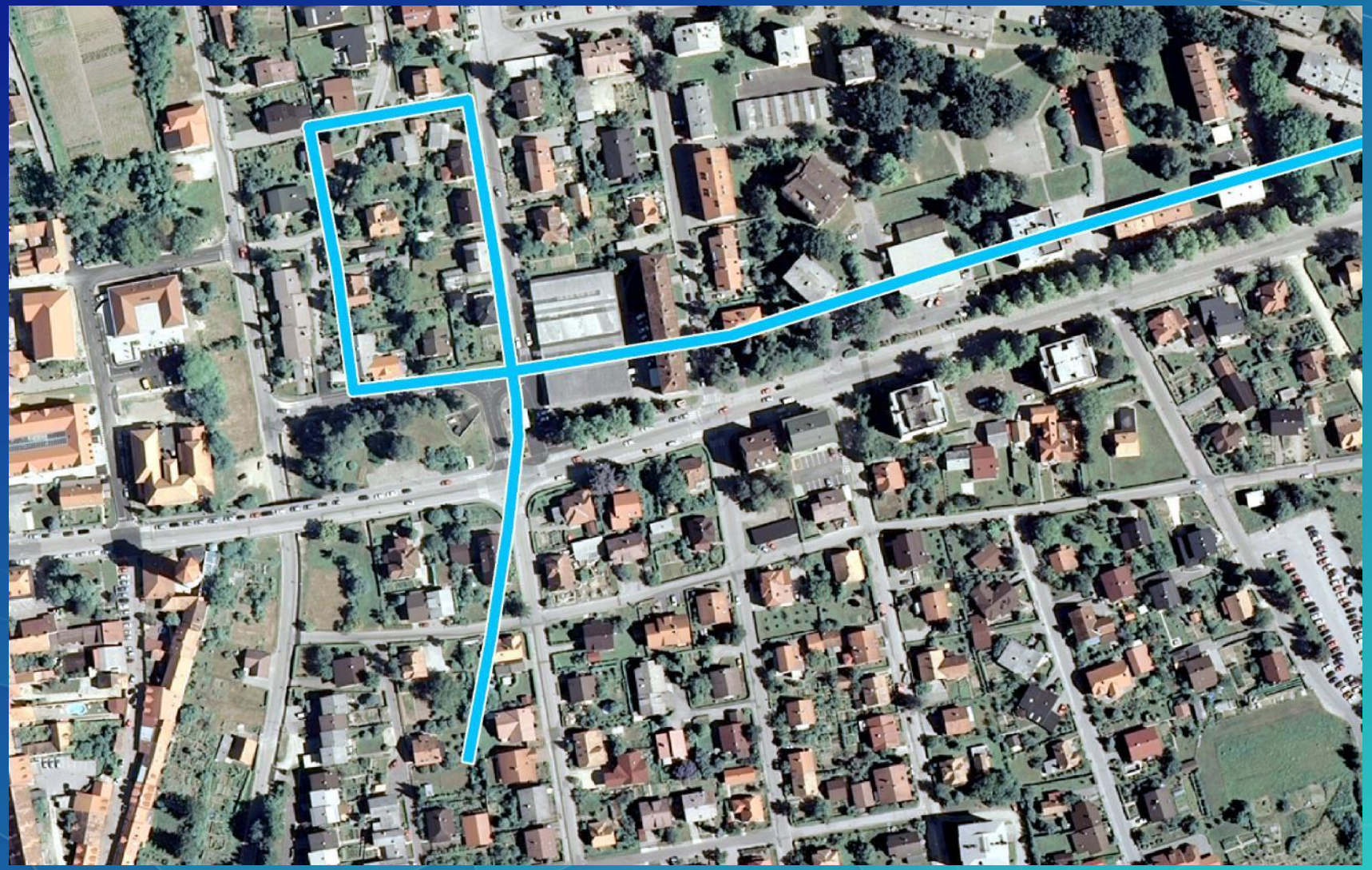
Transforming Means Changing Datum

Earth-centered datum (WGS 84)

Local datum (NAD 27)



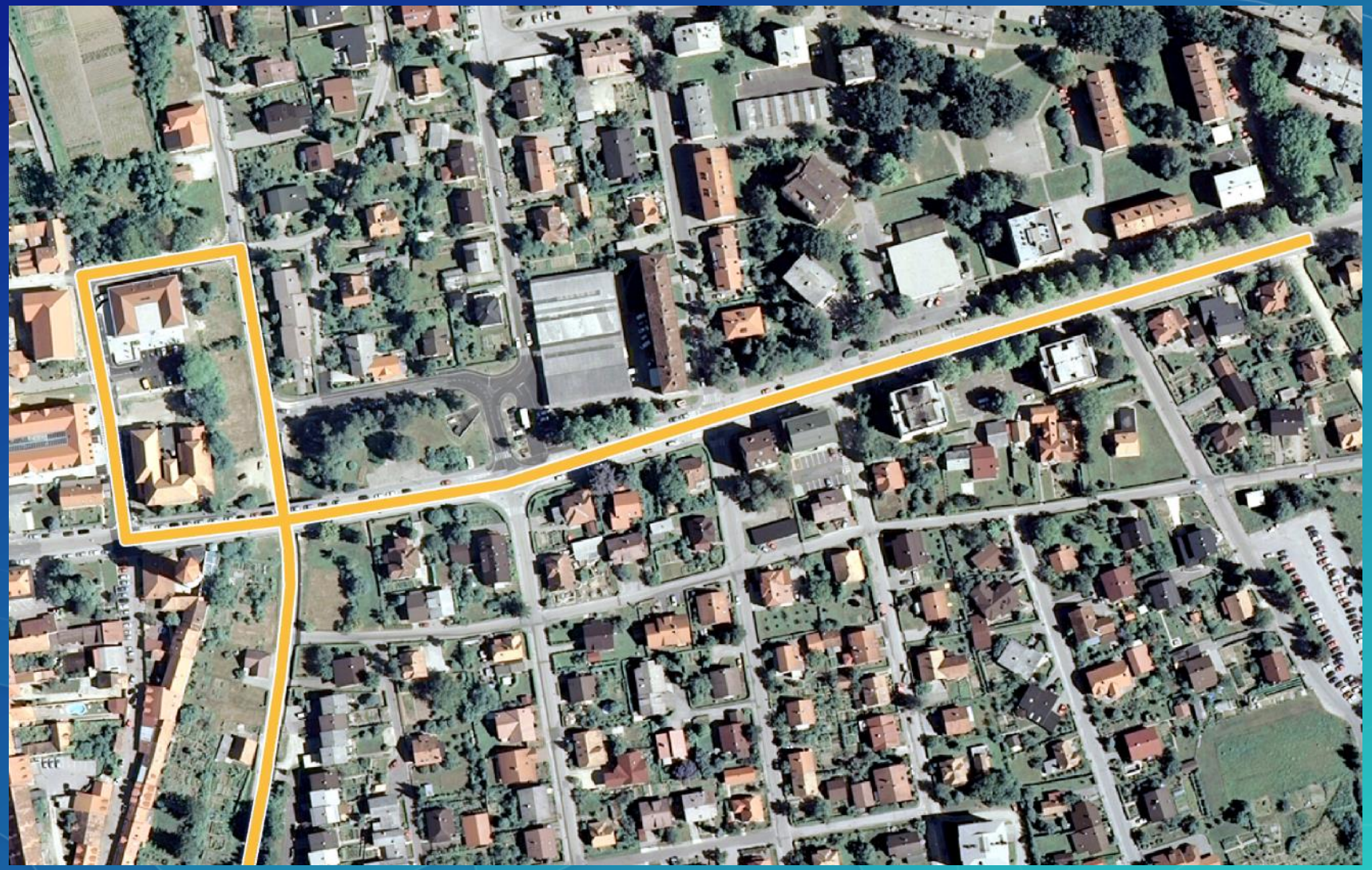
Why do we need to transform our data?



WGS 1984

ED 1950

Why do we need to transform our data?



WGS 1984

ED 1950

Geographic (Datum) Transformation

NAD 1927 → WGS 1984

NAD_1927_To_WGS_1984_1

Geographic (Datum) Transformation

NAD 1927 → WGS 1984

NAD_1927_To_WGS_1984_1

NAD 1927 ← WGS 1984

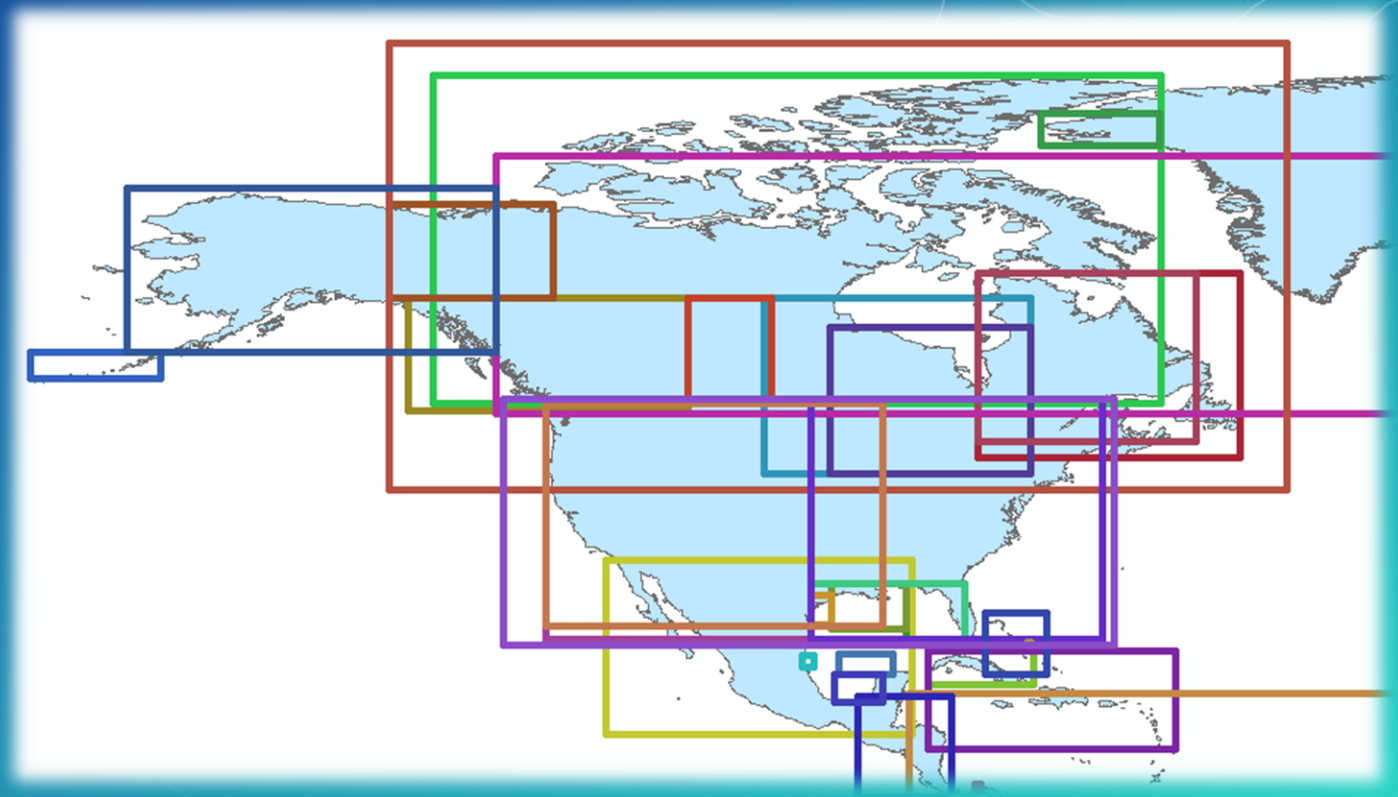
~NAD_1927_To_WGS_1984_1

Defined for Certain Area

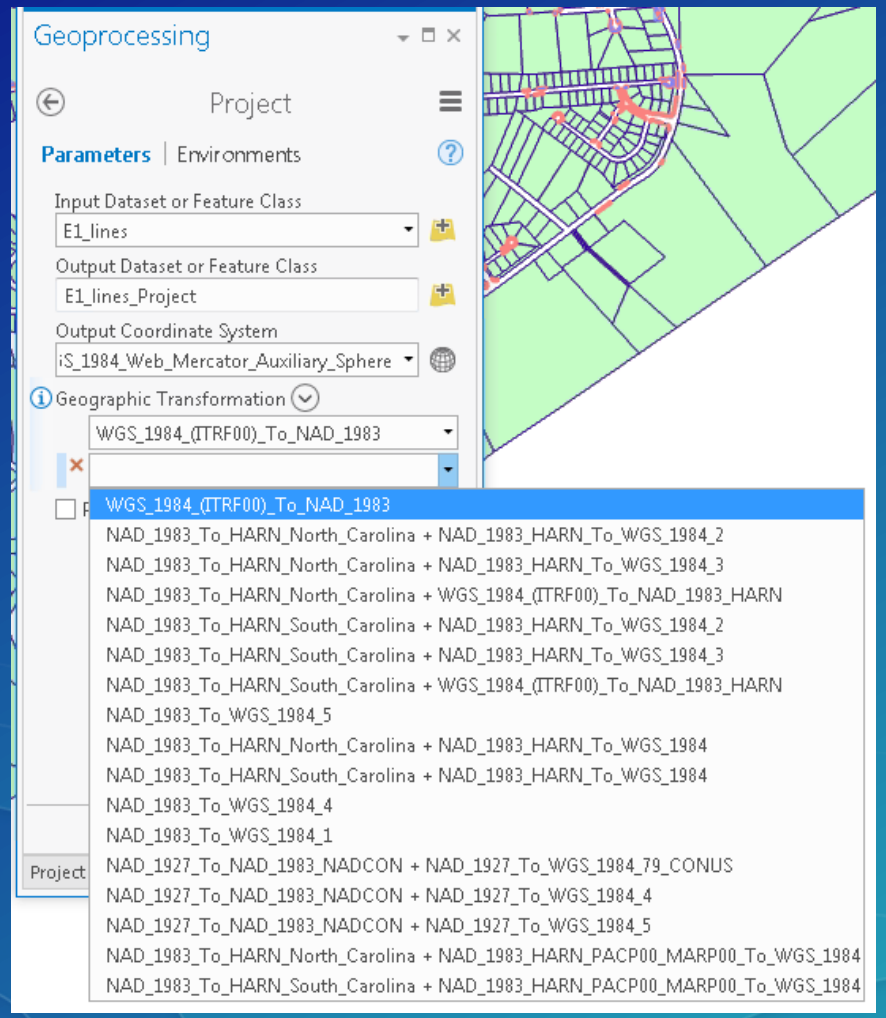
- **33 transformations:**

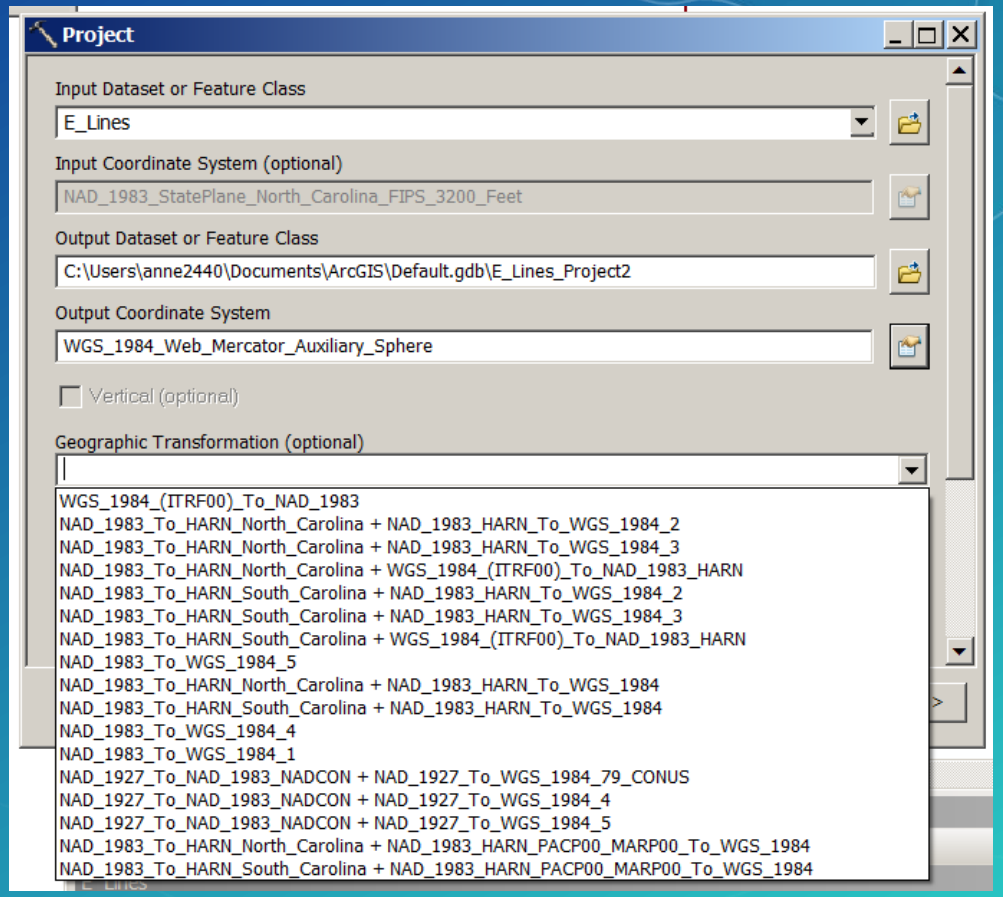
NAD 27

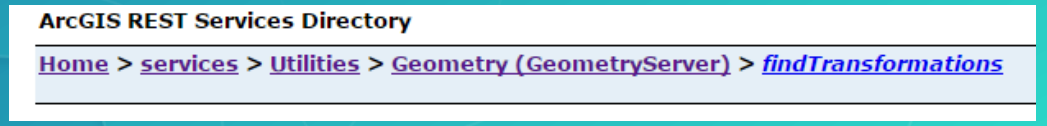
WGS 84



How do I find transformations?







Now you understand…

Coordinate Systems

Projecting your data

Transforming your data

Resources

http://resources.arcgis.com/en/help

- ***ArcMap → Map → Map projections***
- *Developer Help*
  - *List of ArcGIS APIs*

Lining Up Data in ArcGIS, *Margaret Maher*

ESRI Technical paper: Understanding Coordinate Management in the Geodatabase

ESRI Technical paper: *Understanding Geometric Processing in ArcGIS*

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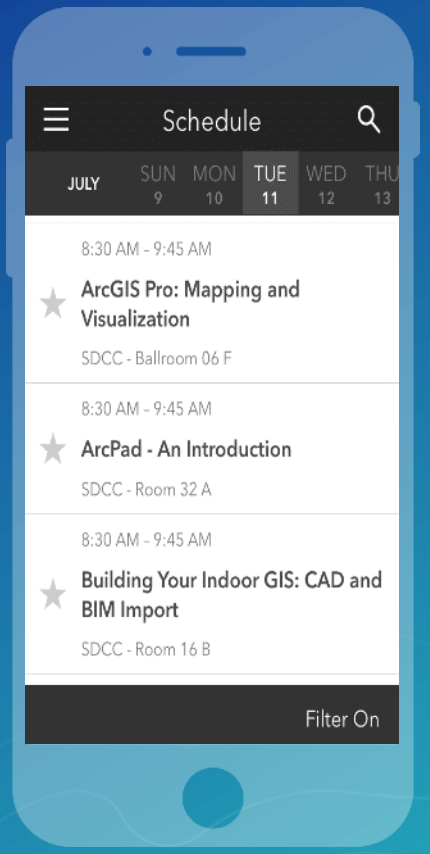
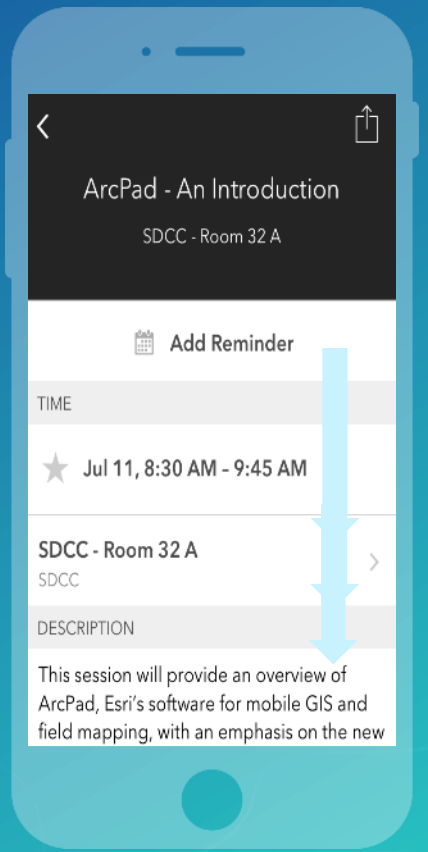
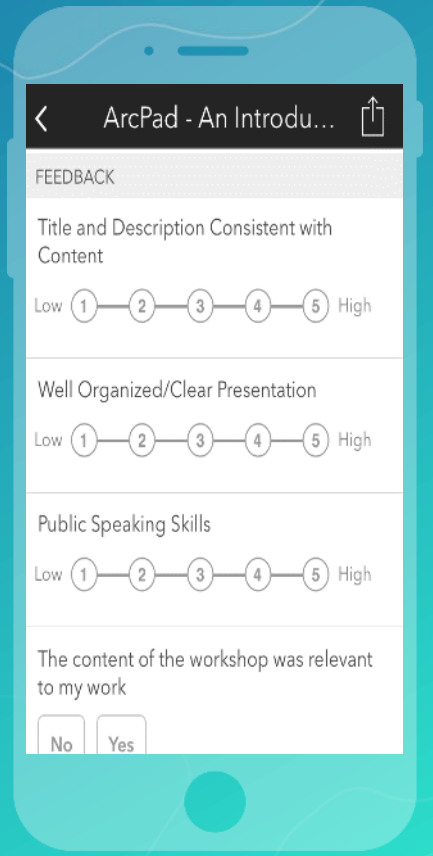


Scroll down to find the survey



Complete Answers and Select "Submit"



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THE SCIENCE OF WHERE