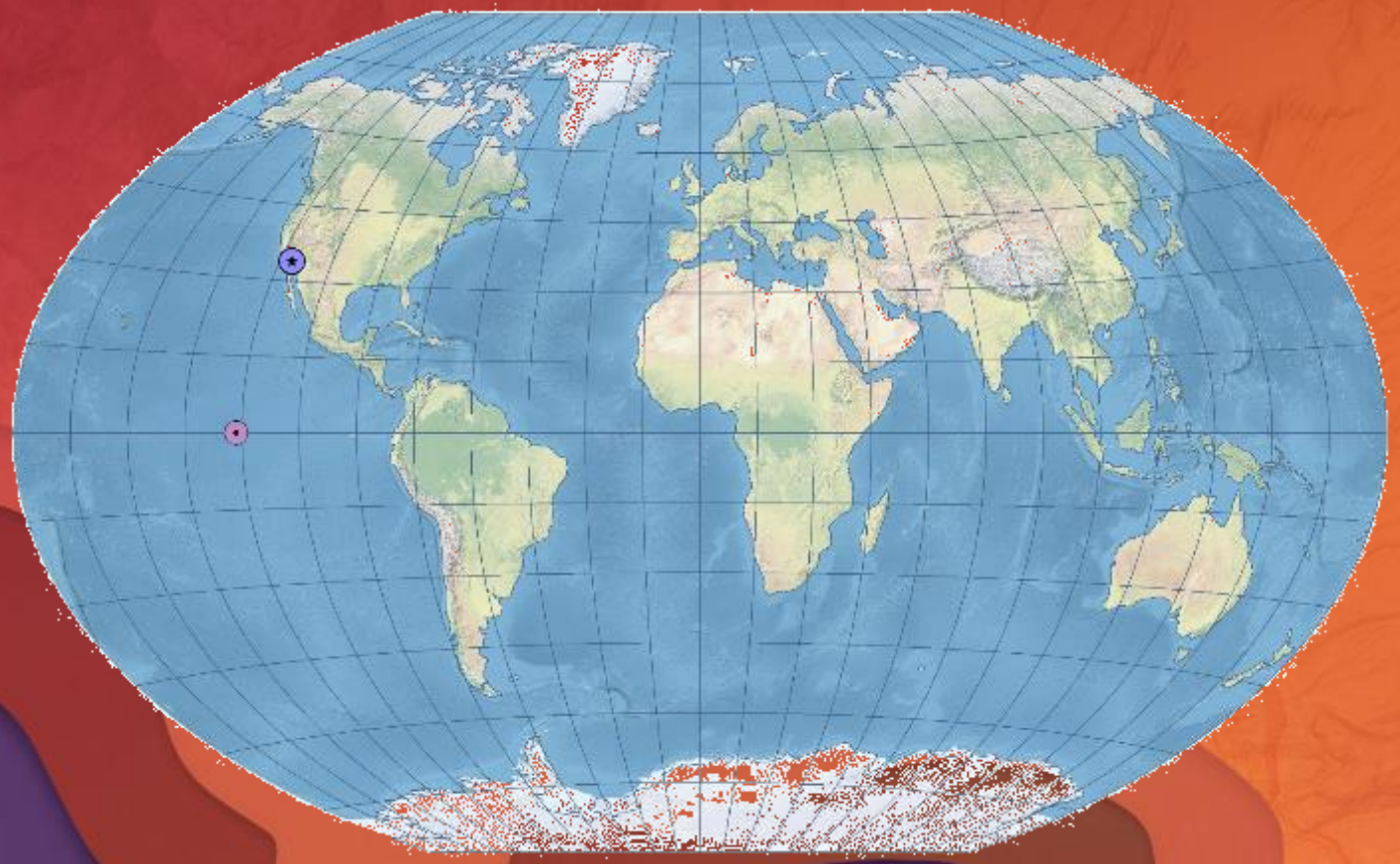
Coordinate Systems and Datum Transformation in ArcGIS

Brittney White and Melita Kennedy



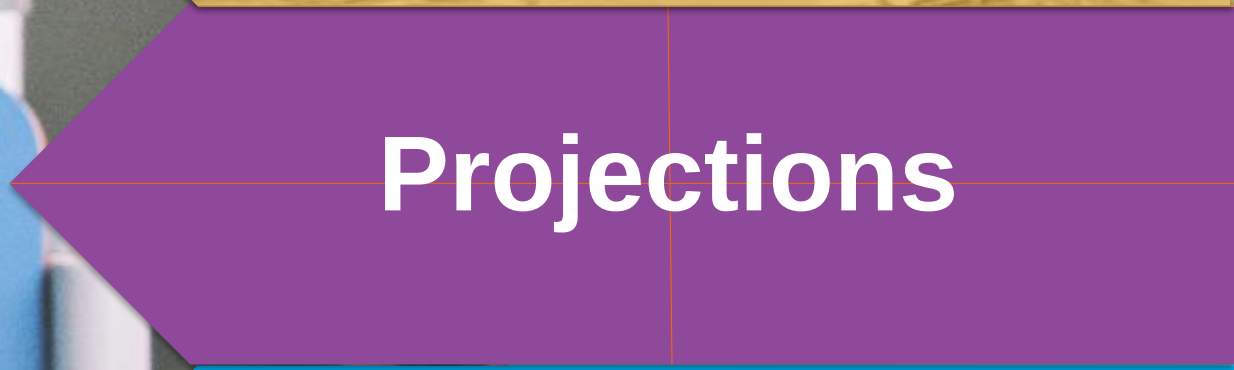
Where is my data?

Problem

Coordinate
Systems

Horizontal

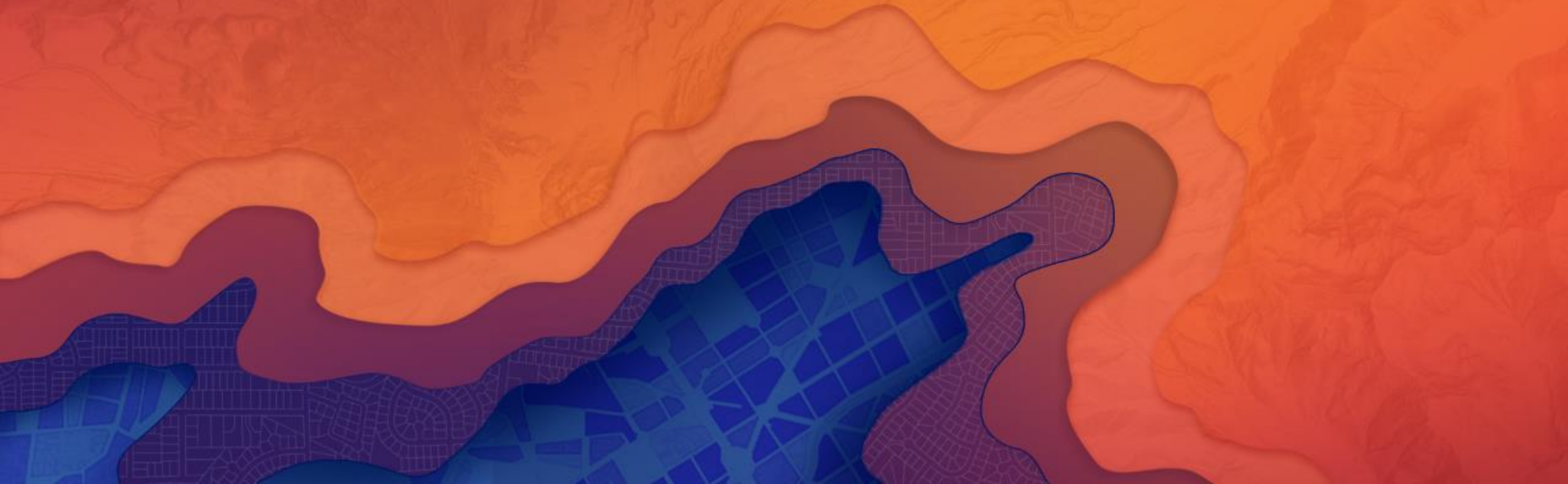
Vertical


Projections

Transformations

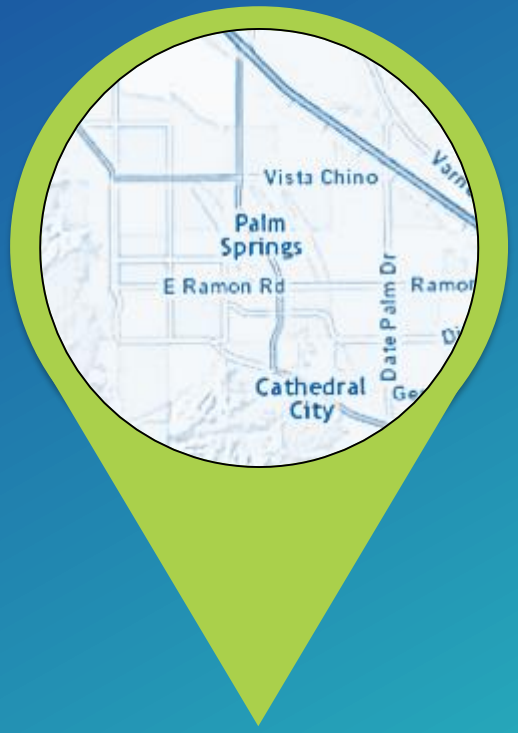
Horizontal coordinate systems

Geographic and Projected

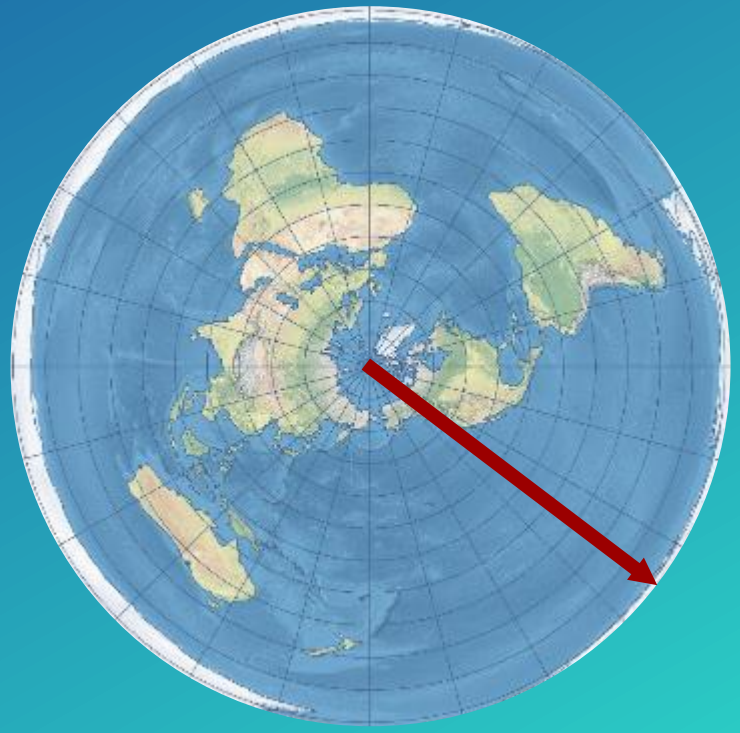


What does a coordinate system tell us?

Distance



Location



Direction

Distance

Q: How far is it from San Francisco to Los Angeles?

352.34 miles

690.67 kilometers

567.03 kilometers

620111.549 yards

Distance

Q: How far is it from San Francisco to Los Angeles?

A: It depends on the coordinate system.

- 352.34 miles
- 690.67 kilometers
- 567.03 kilometers
- 620111.549 yards

Location

Q: What are the coordinates for Los Angeles?

(-118.25, 34.05)

(1276.333, 2421.545)

(2054060.514, 3897101.109)

(-13163527.521, 4035514.817)

Location

Q: What are the coordinates for Los Angeles?

A: It depends on the coordinate system.

(-118.25, 34.05)

(1276.333, 2421.545)

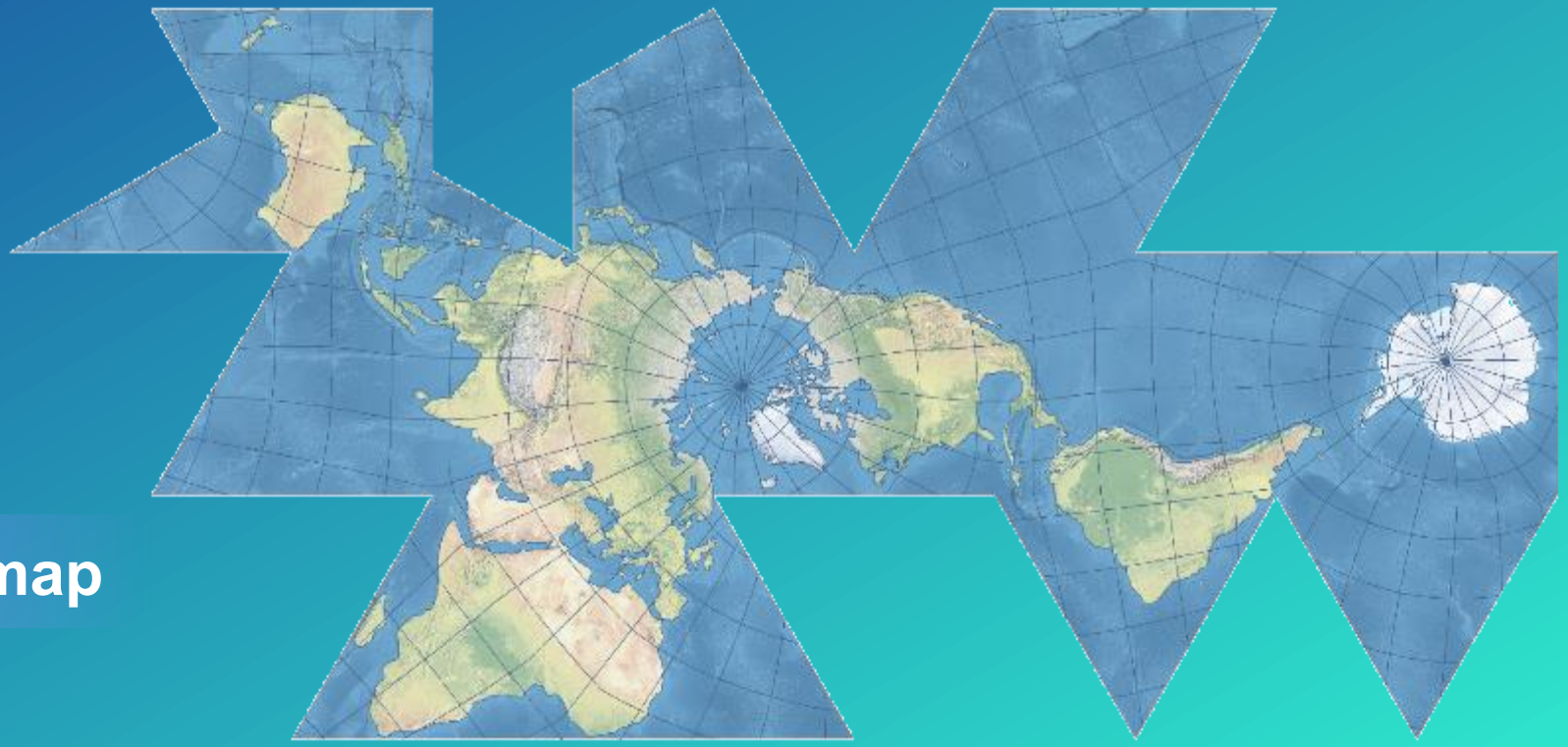
(2054060.514, 3897101.109)

(-13163527.521, 4035514.817)

Direction

Q: In which direction is the North Pole?

- Down
- To the right
- Up
- Can’t, not on the map

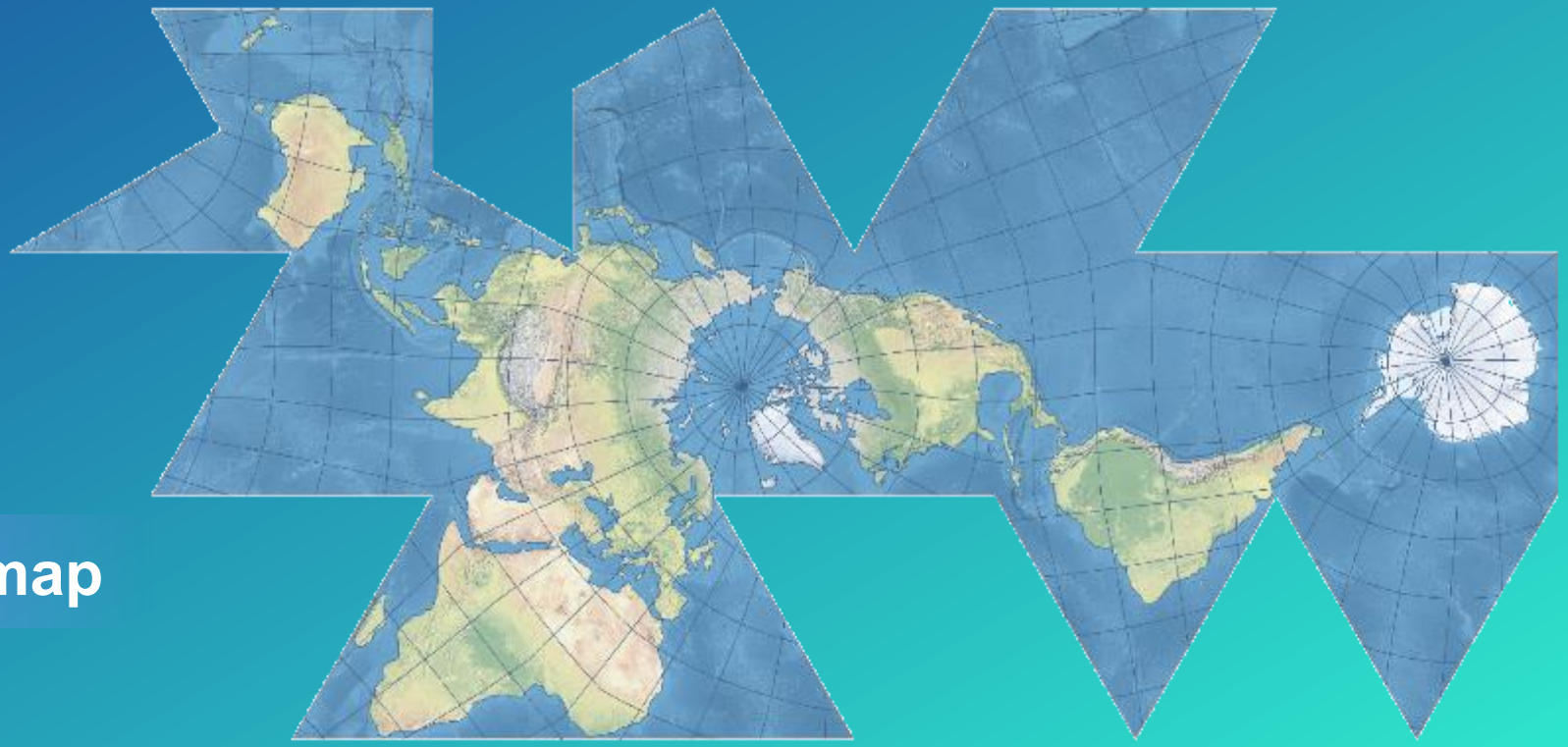


Direction

Q: In which direction is the North Pole?

A: It depends on the coordinate system.

- Down
- To the right
- Up
- Can’t, not on the map



Two Kinds of Horizontal Coordinate Systems

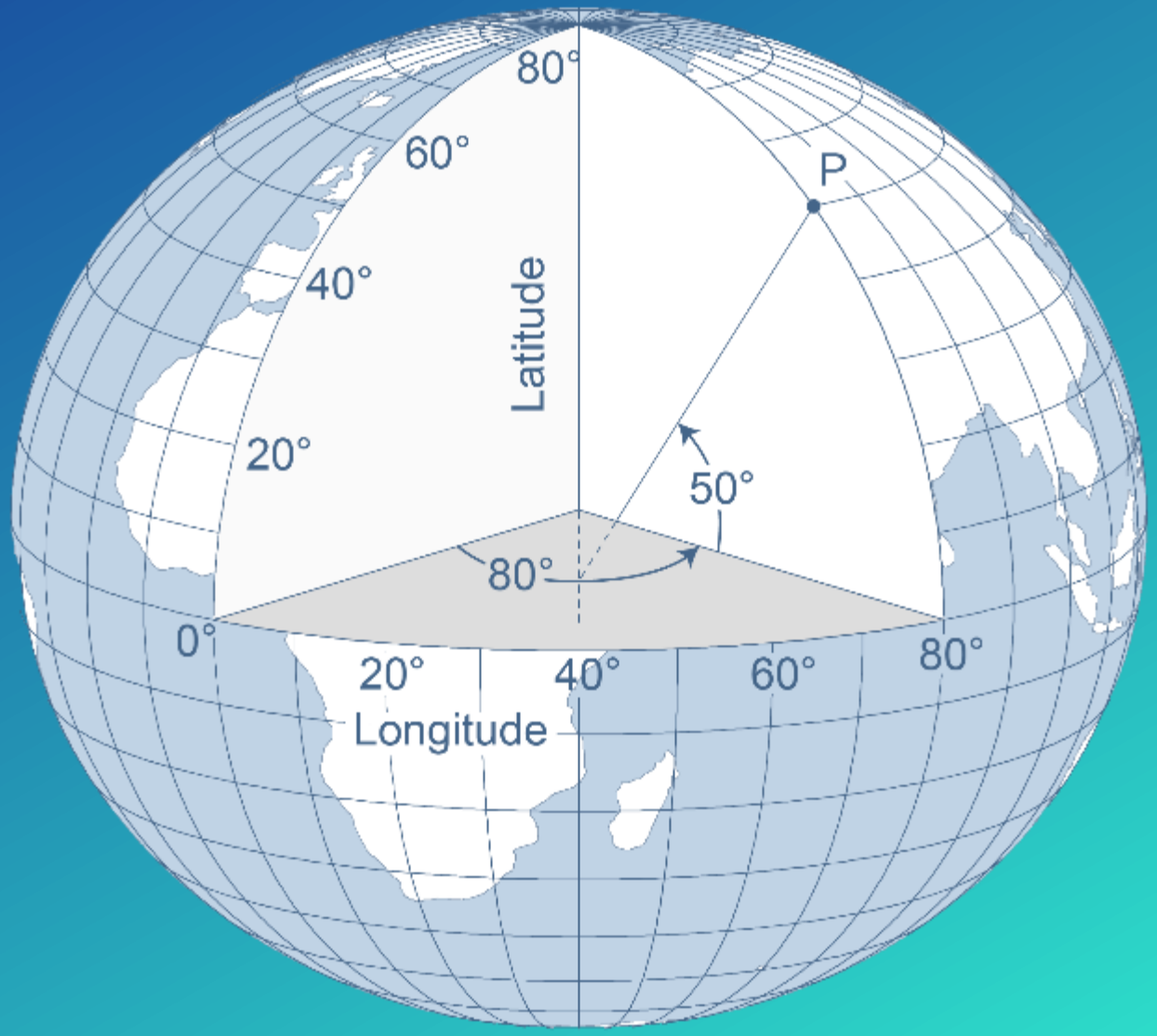
Geographic coordinate system

Projected coordinate system

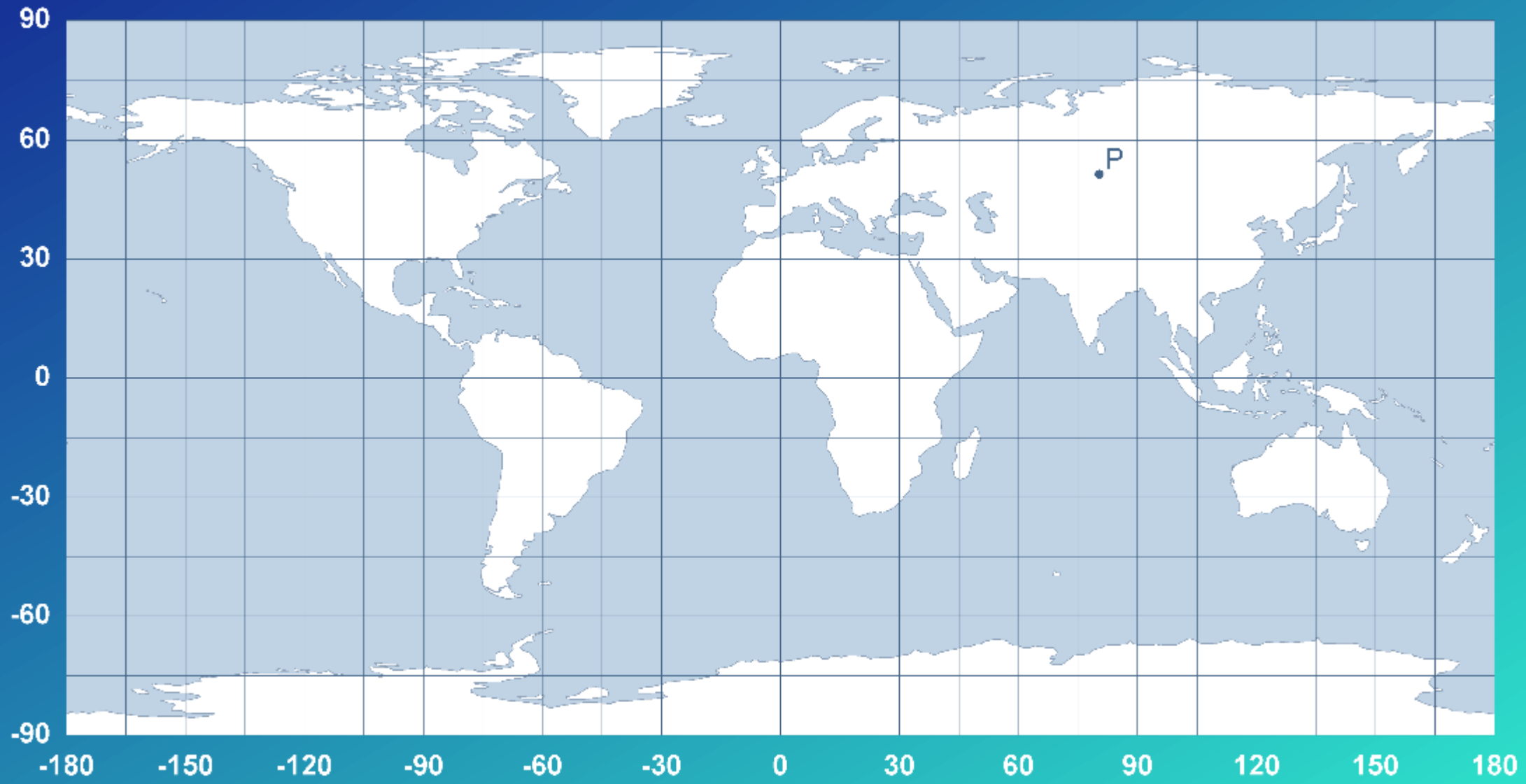
Geographic Coordinate System (GCS)

- 3D spherical surface

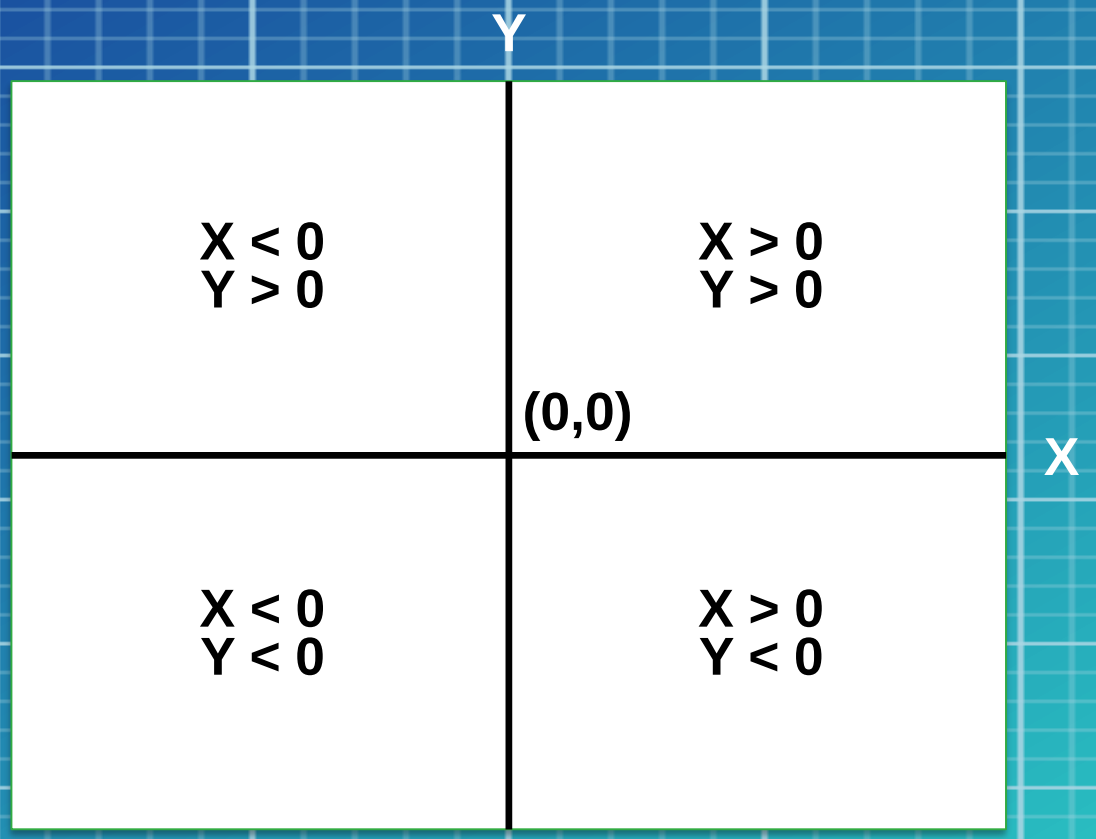
- Point P has:
  - Longitude – 80º E
  - Latitude – 50º N



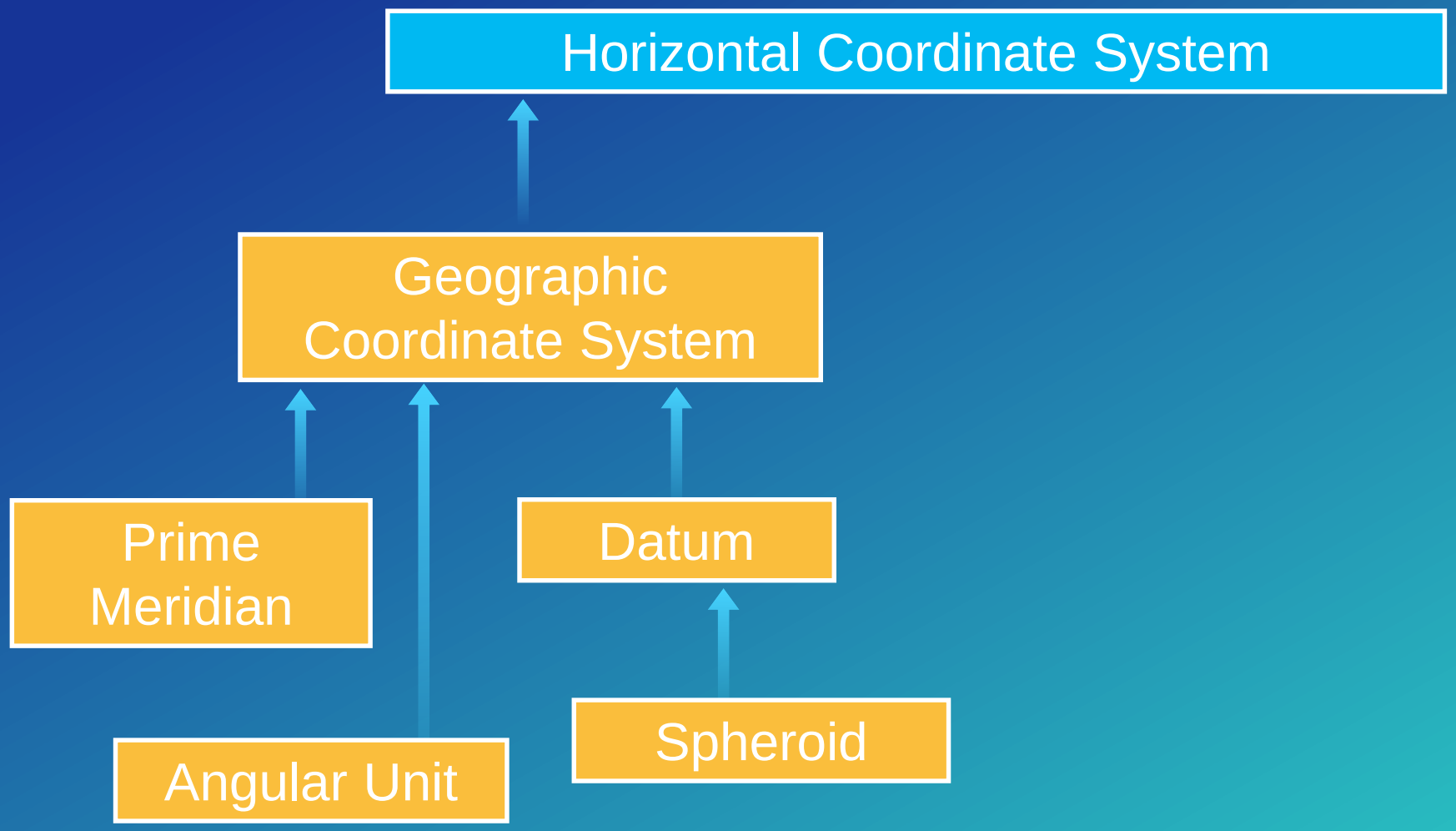
Geographic Coordinate System (GCS)

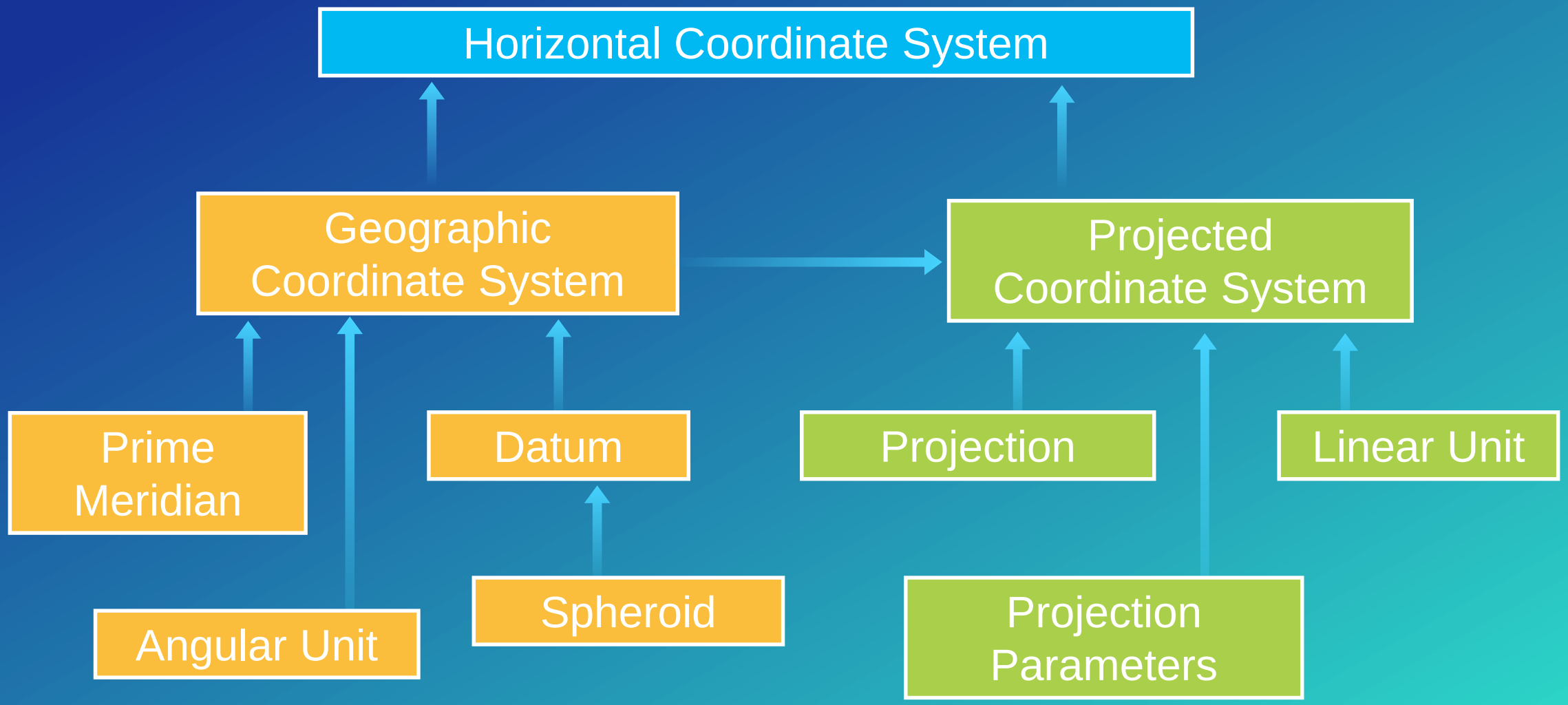


Projected Coordinate System (PCS)



Horizontal Coordinate System

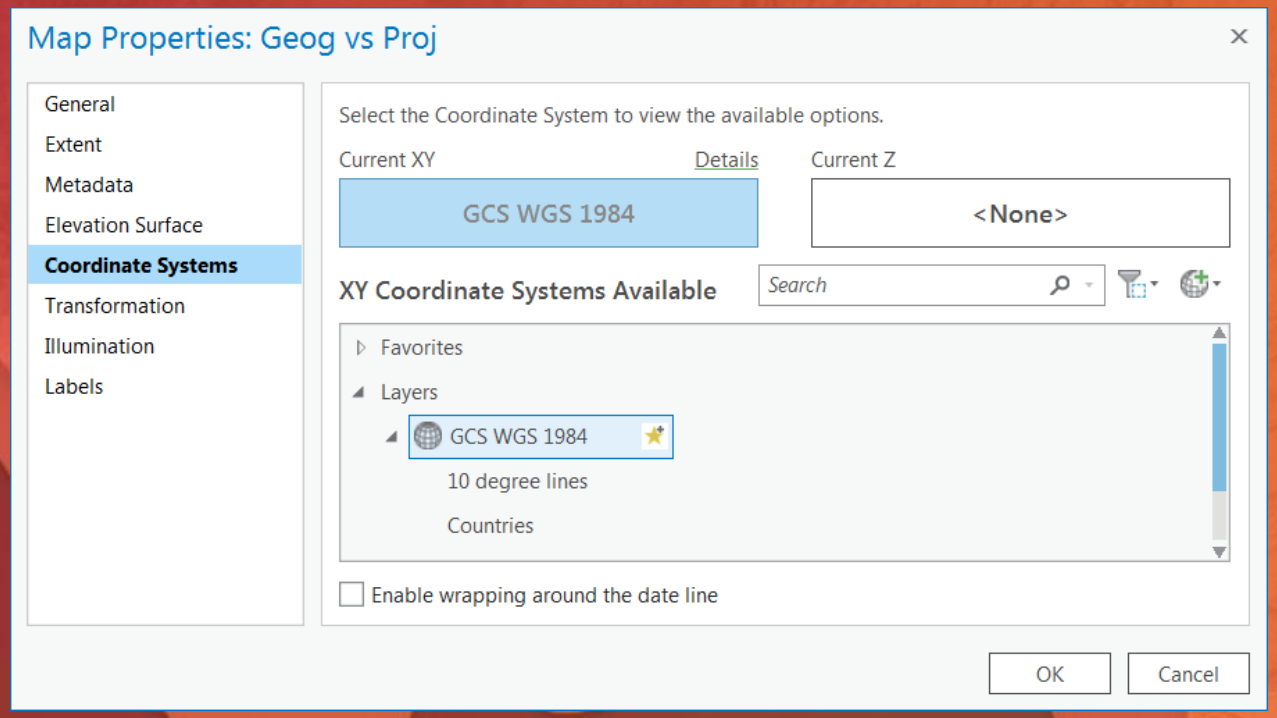

Horizontal Coordinate System
Geographic Coordinate System
Prime Meridian
Angular Unit
Datum
Spheroid


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

Two Ways to Specify a Coordinate System

Well-known ID

Well-known text



Horizontal coordinate systems

Vertical coordinate systems

Height

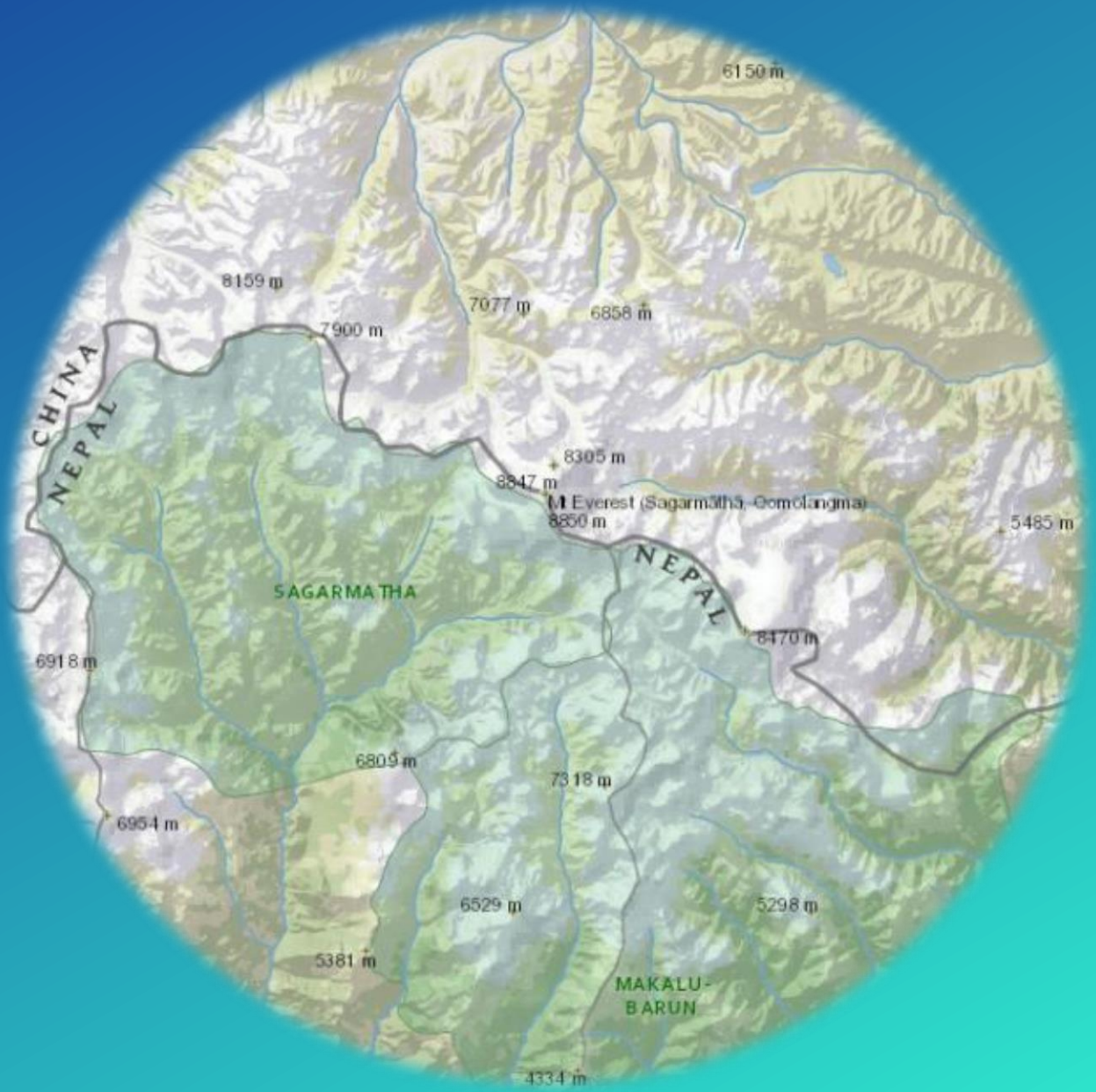
- Q: How high is Mount Everest?

8844.43 meters

29029 feet

8.850 kilometers

29017.16 feet



Height

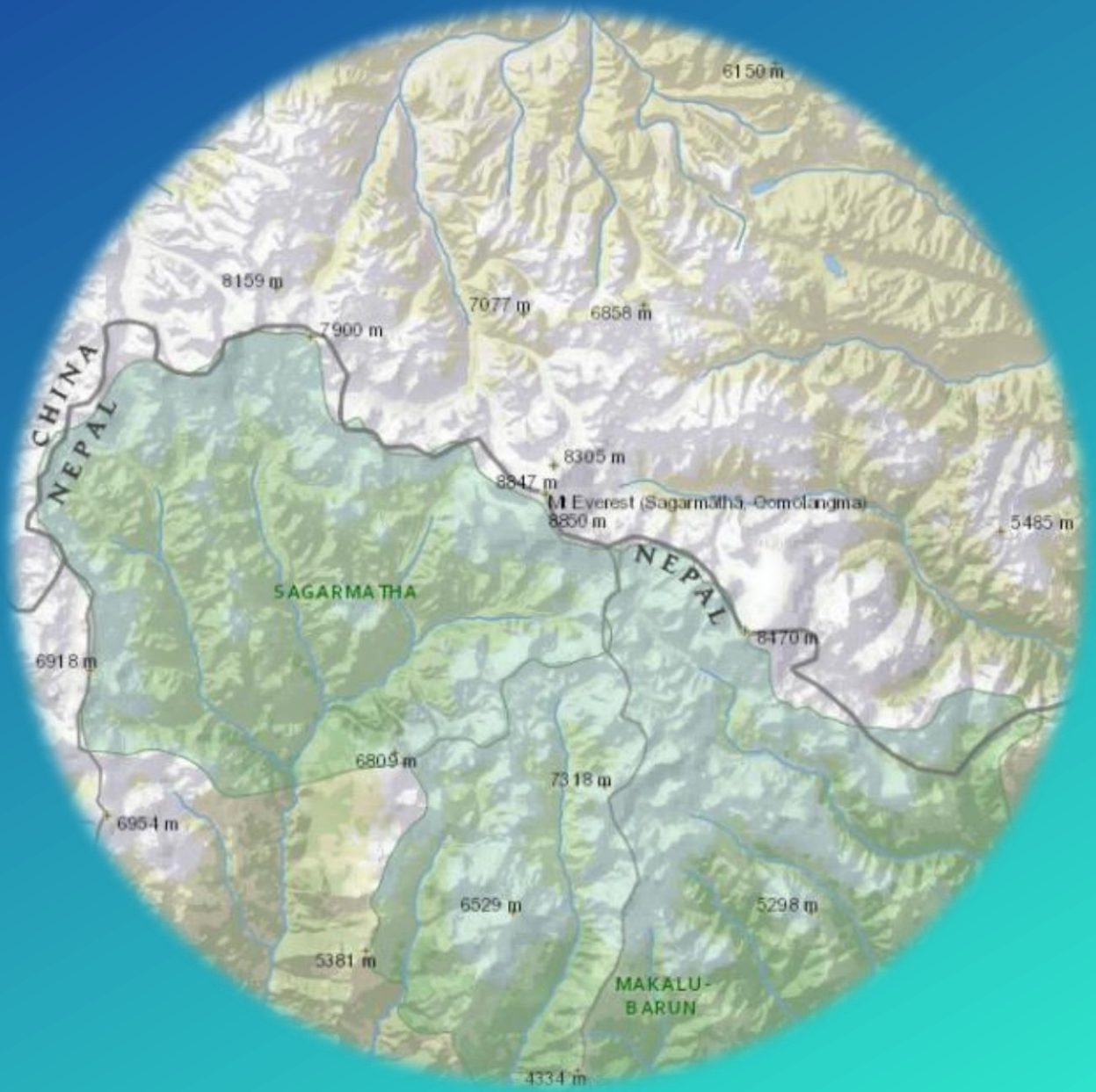
- Q: How high is Mount Everest?
- A: It depends on the vertical coordinate system.

8844.43 meters

29029 feet

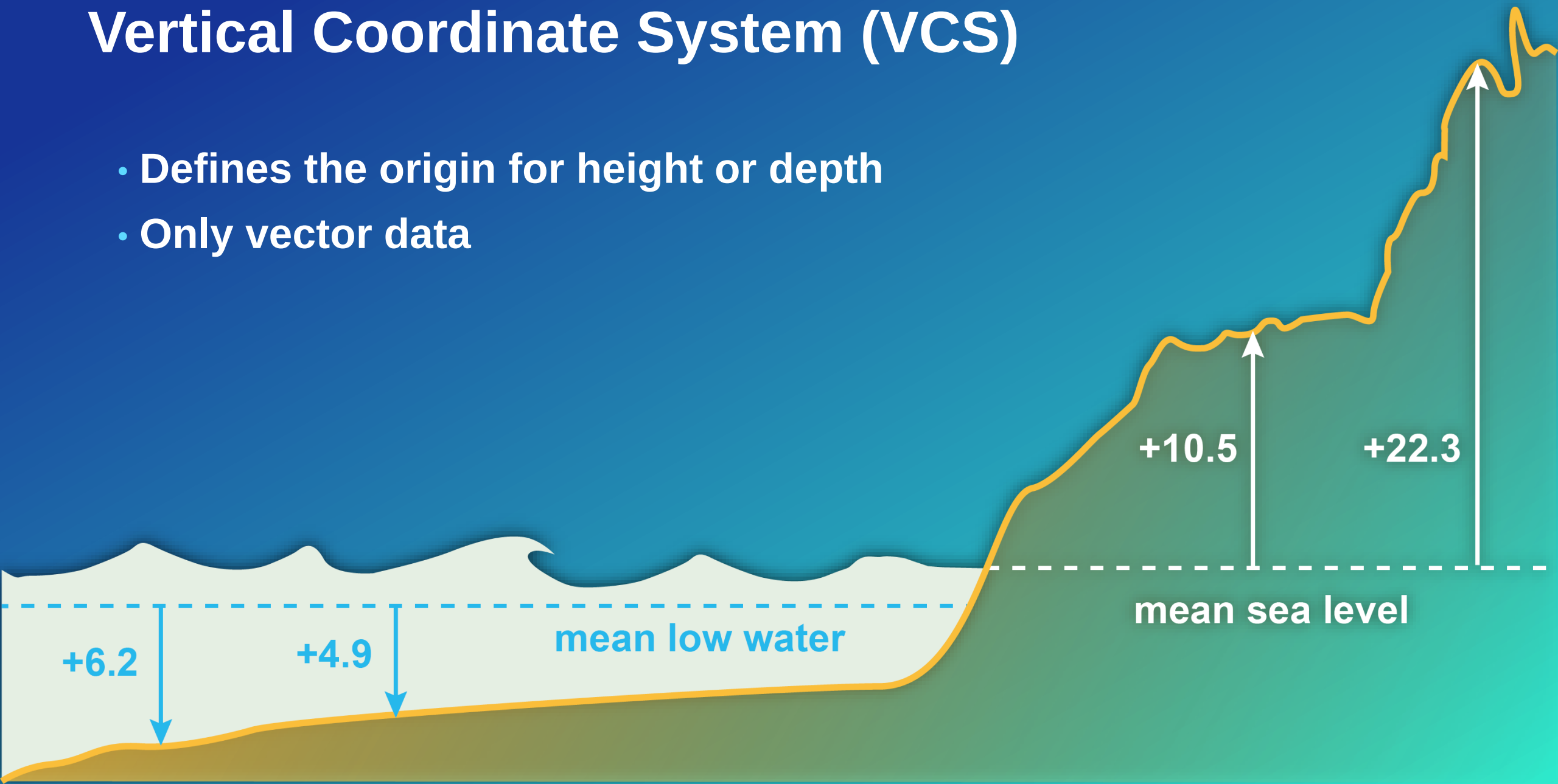
8.850 kilometers

29017.16 feet



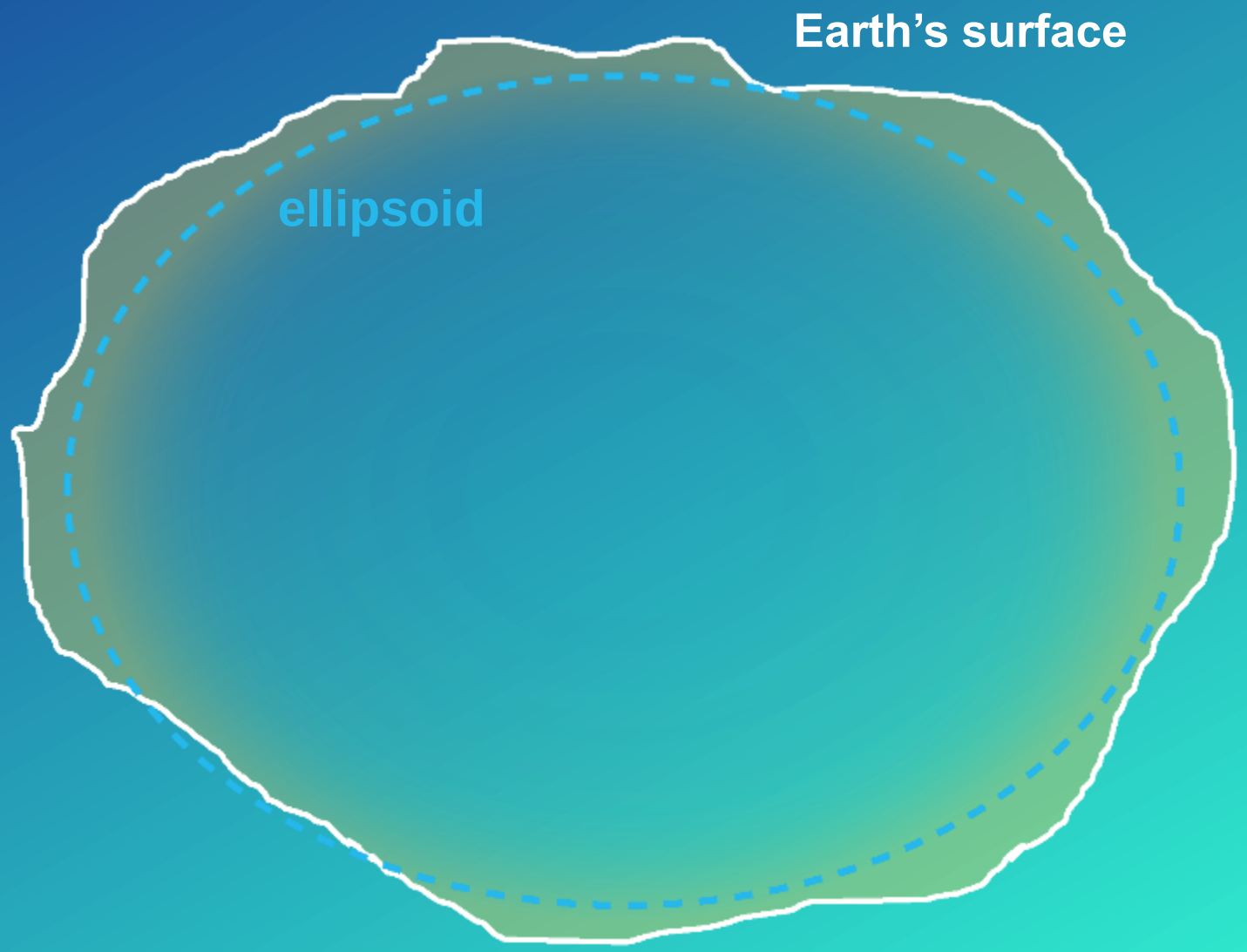
Vertical Coordinate System (VCS)

- Defines the origin for height or depth
- Only vector data



The Origin for Height or Depth

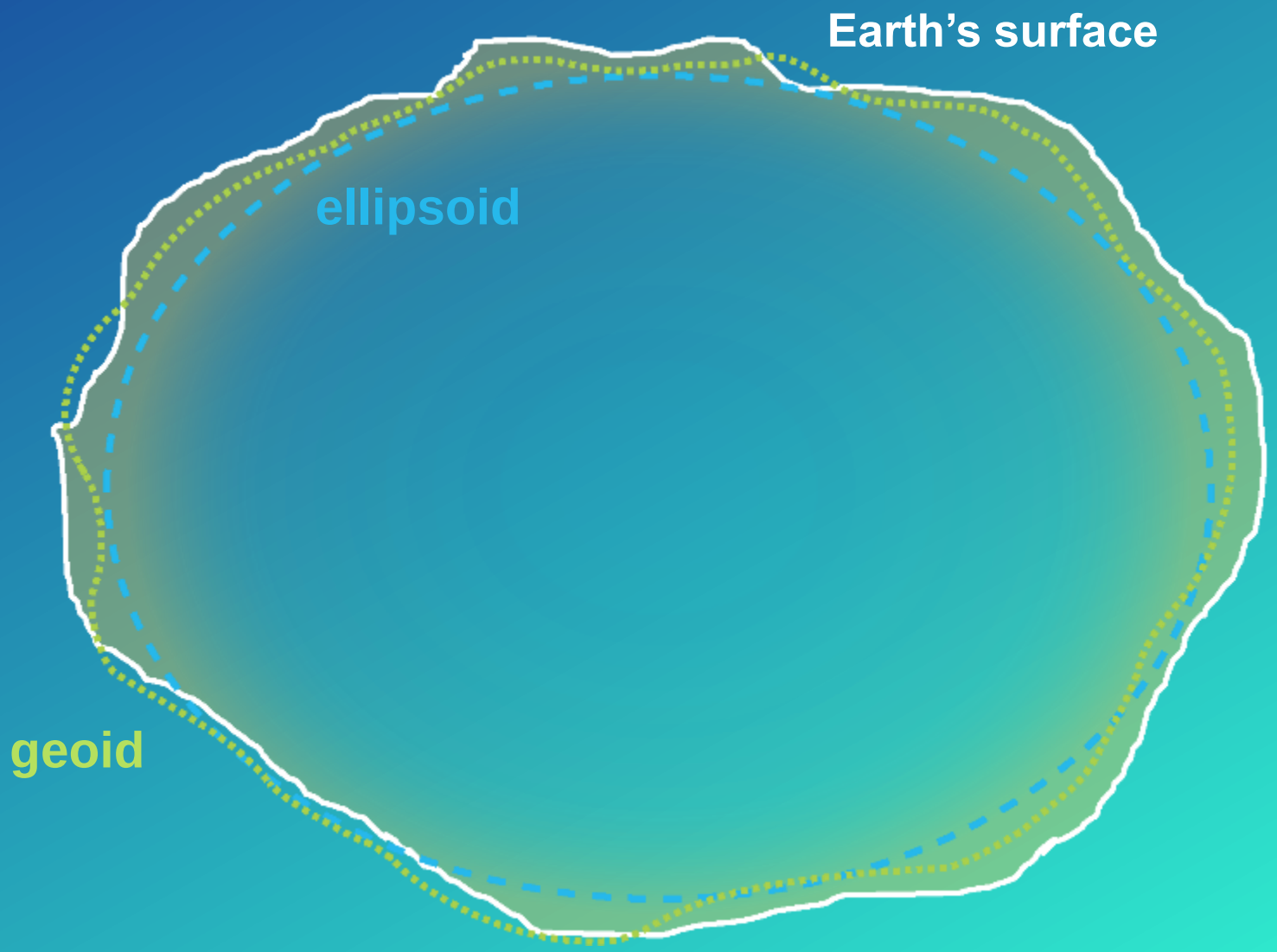
Geometric model



The Origin for Height or Depth

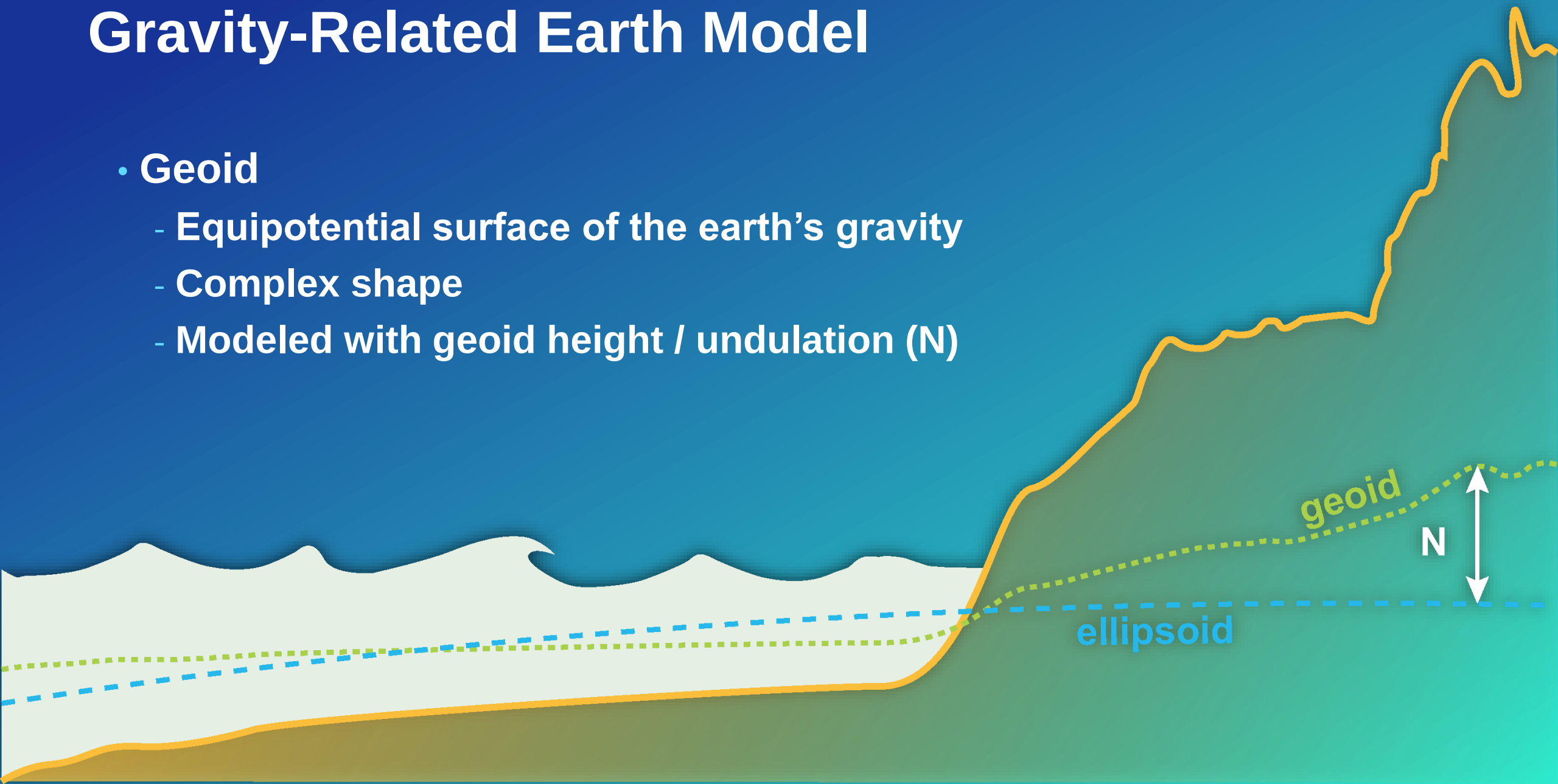
Geometric model

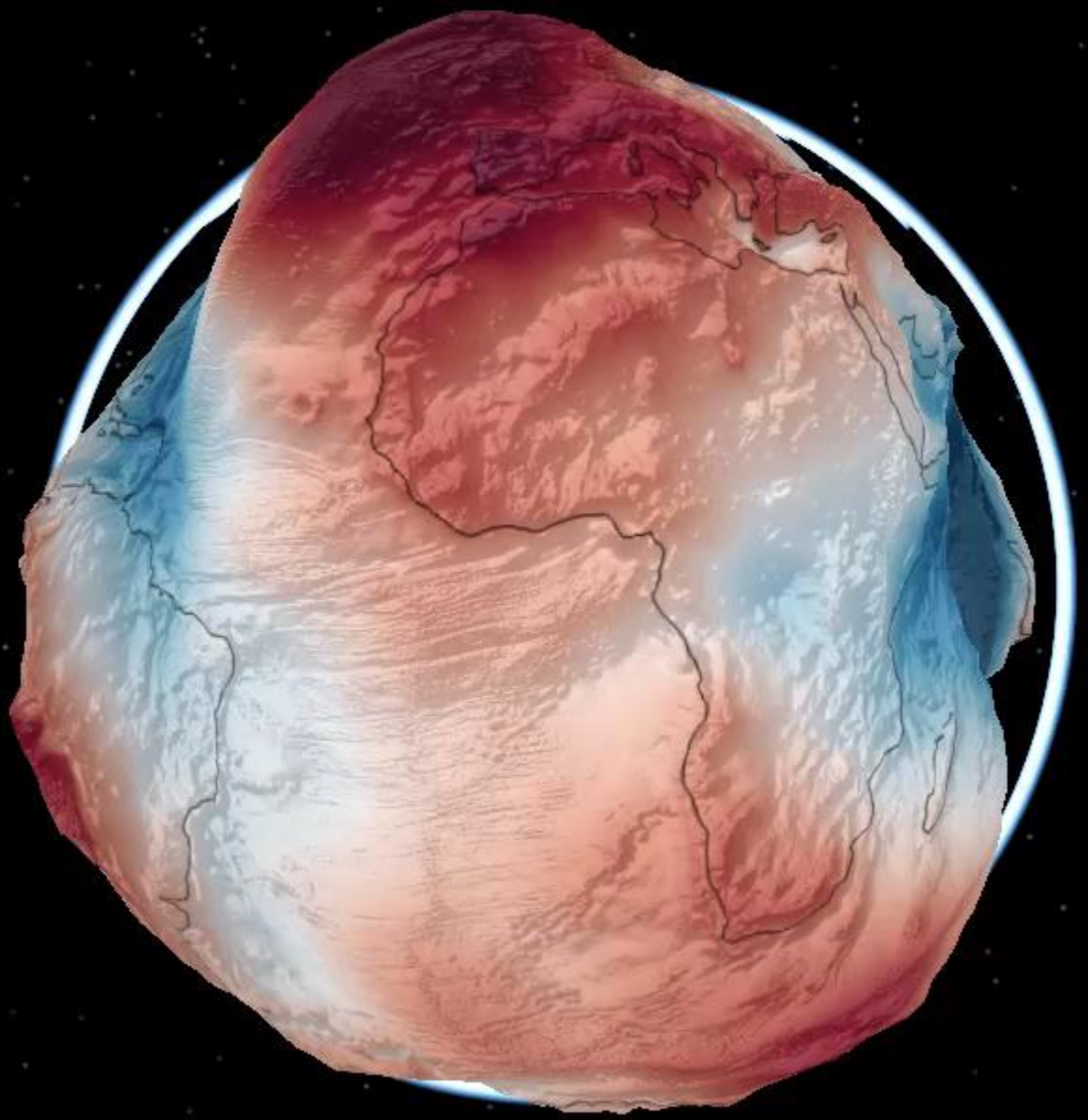
Gravity related model



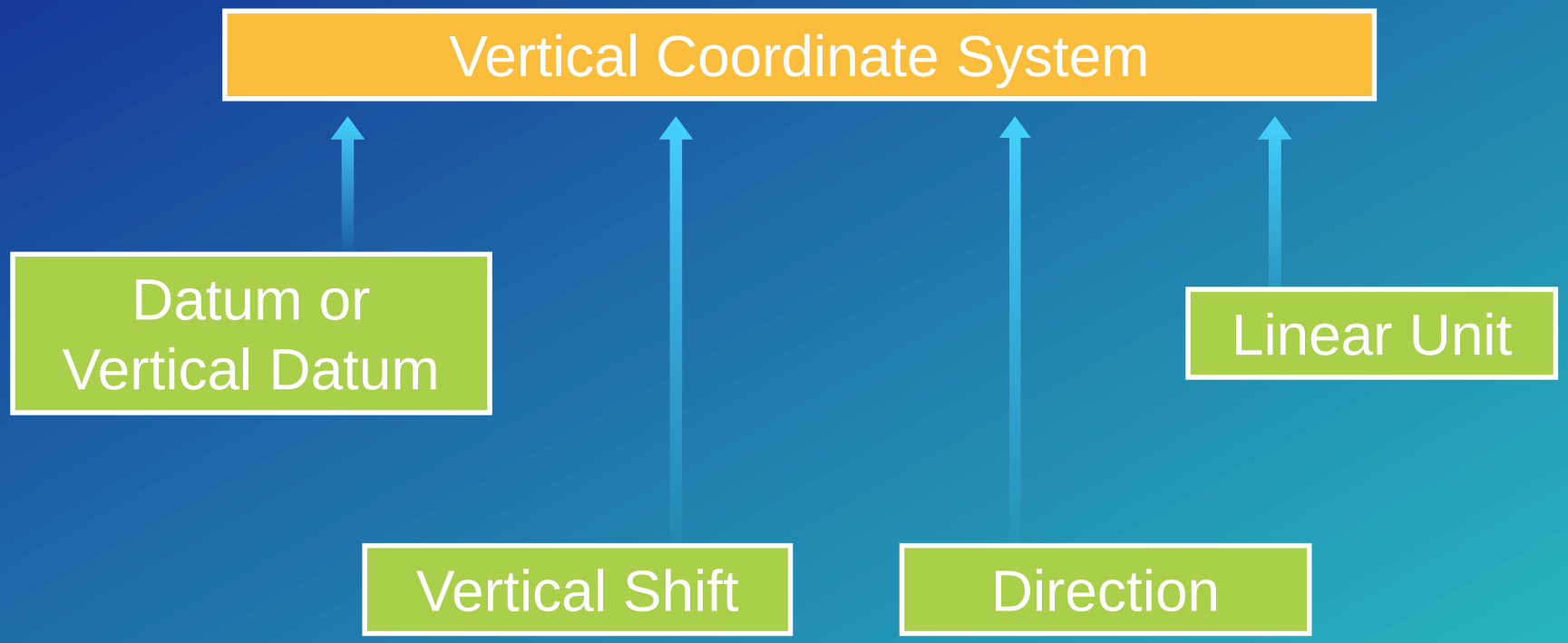
Gravity-Related Earth Model

- Geoid
  - Equipotential surface of the earth's gravity
  - Complex shape
  - Modeled with geoid height / undulation (N)



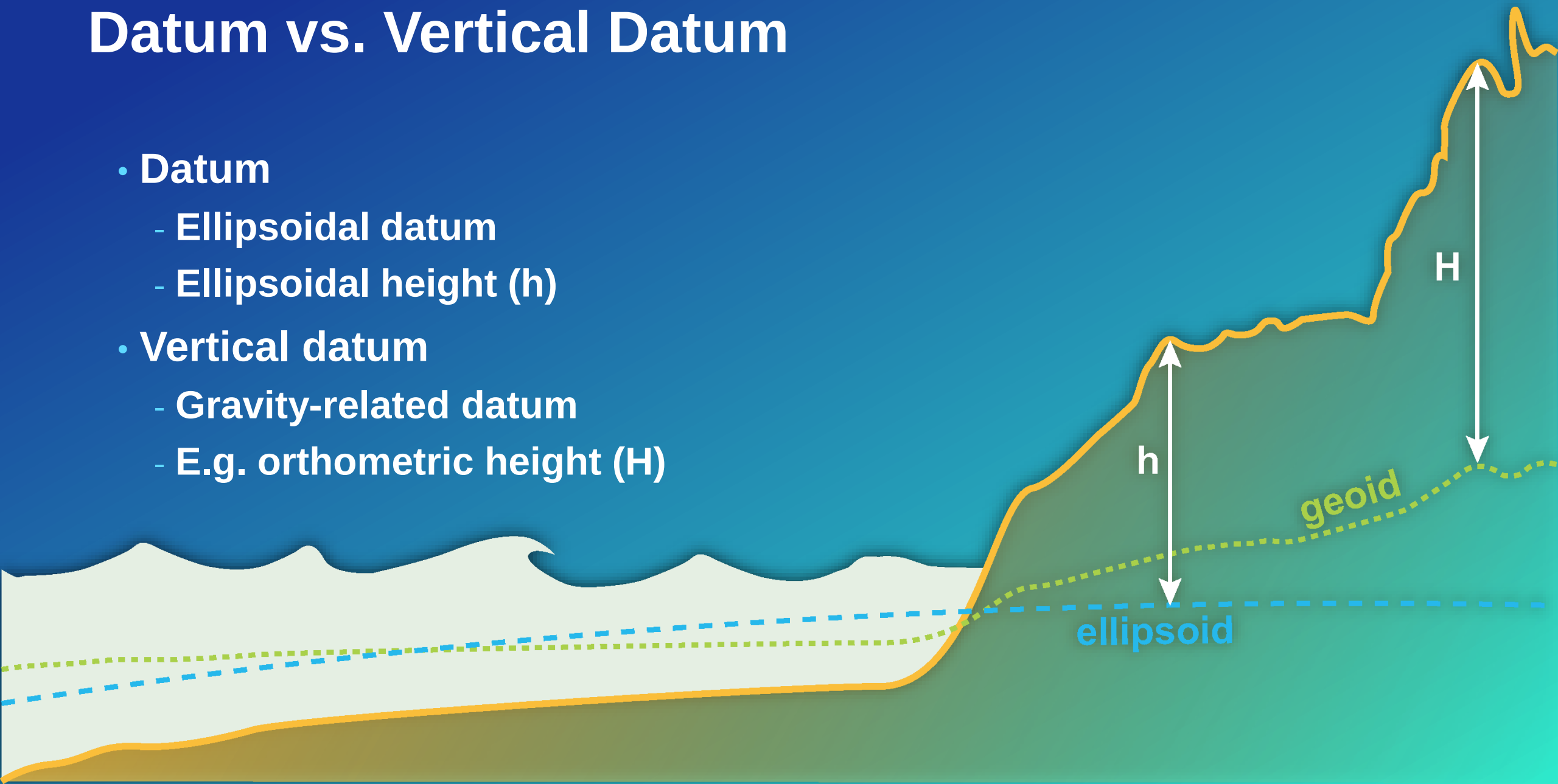


Vertical Coordinate System


Vertical Coordinate System
Datum or
Vertical Datum
Vertical Shift
Direction
Linear Unit

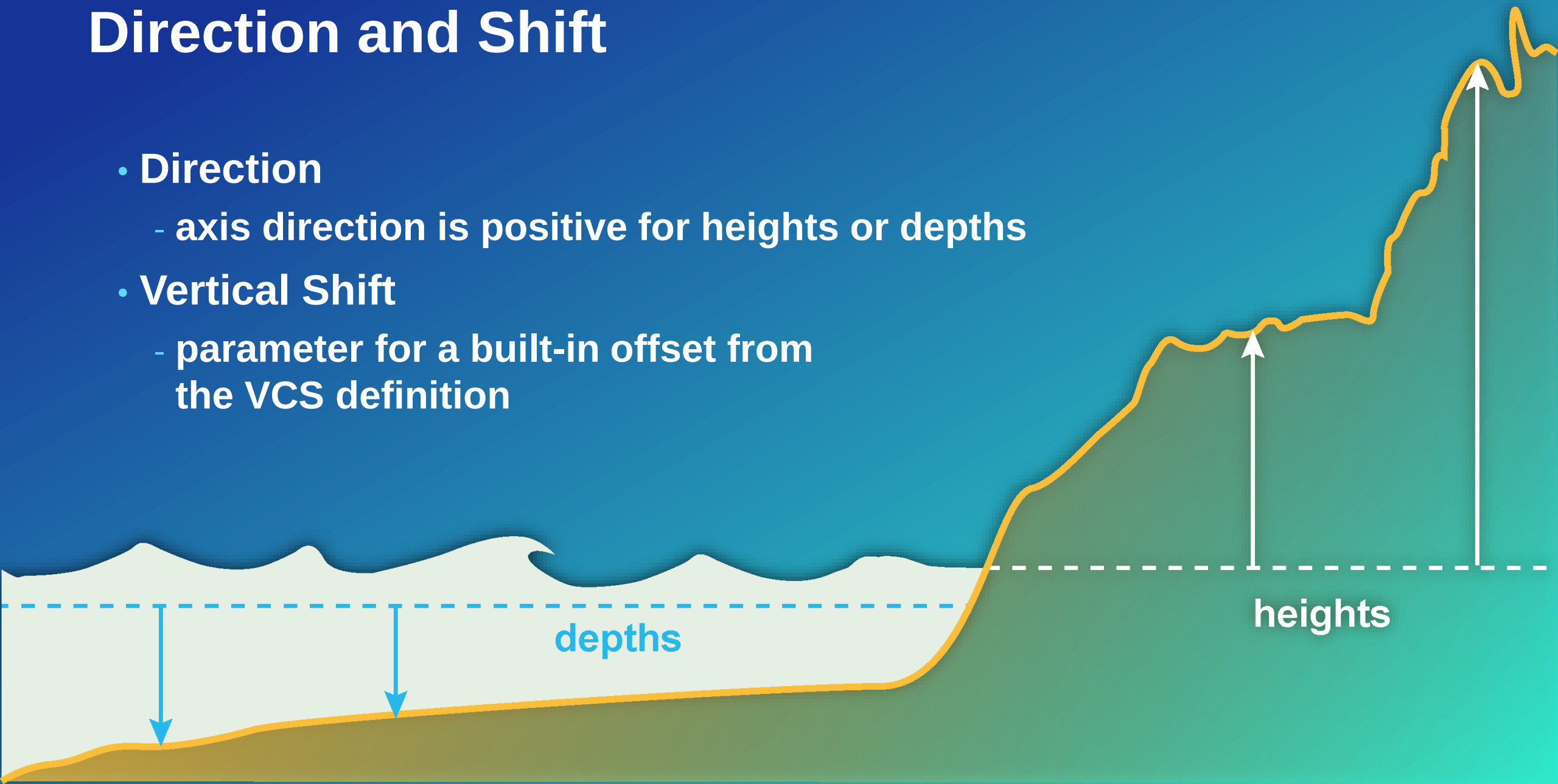
Datum vs. Vertical Datum

- Datum
  - Ellipsoidal datum
  - Ellipsoidal height (h)
- Vertical datum
  - Gravity-related datum
  - E.g. orthometric height (H)



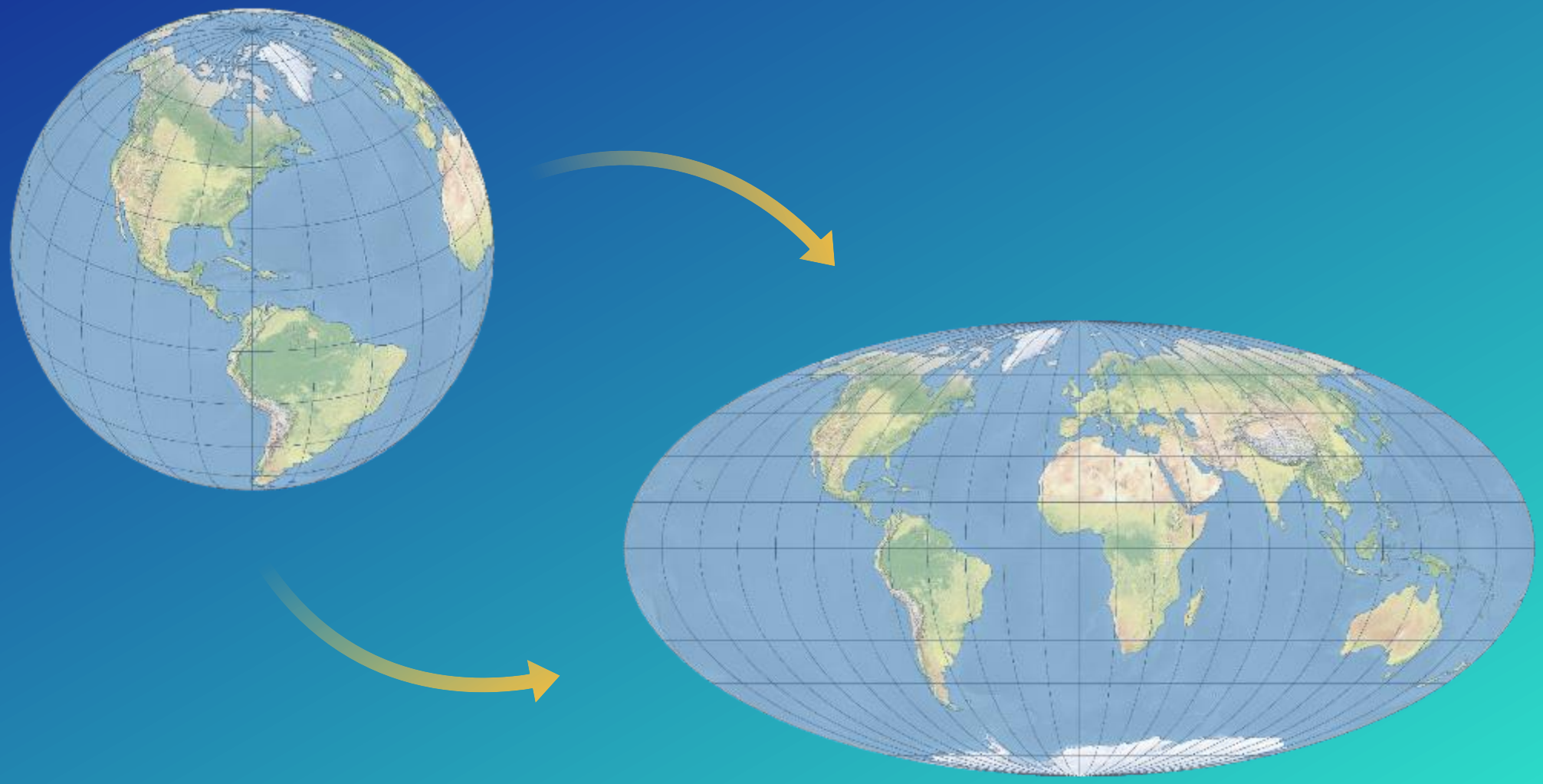
Direction and Shift

- **Direction**
  - axis direction is positive for heights or depths
- **Vertical Shift**
  - parameter for a built-in offset from the VCS definition



Projections

Projecting to a Different Coordinate System



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

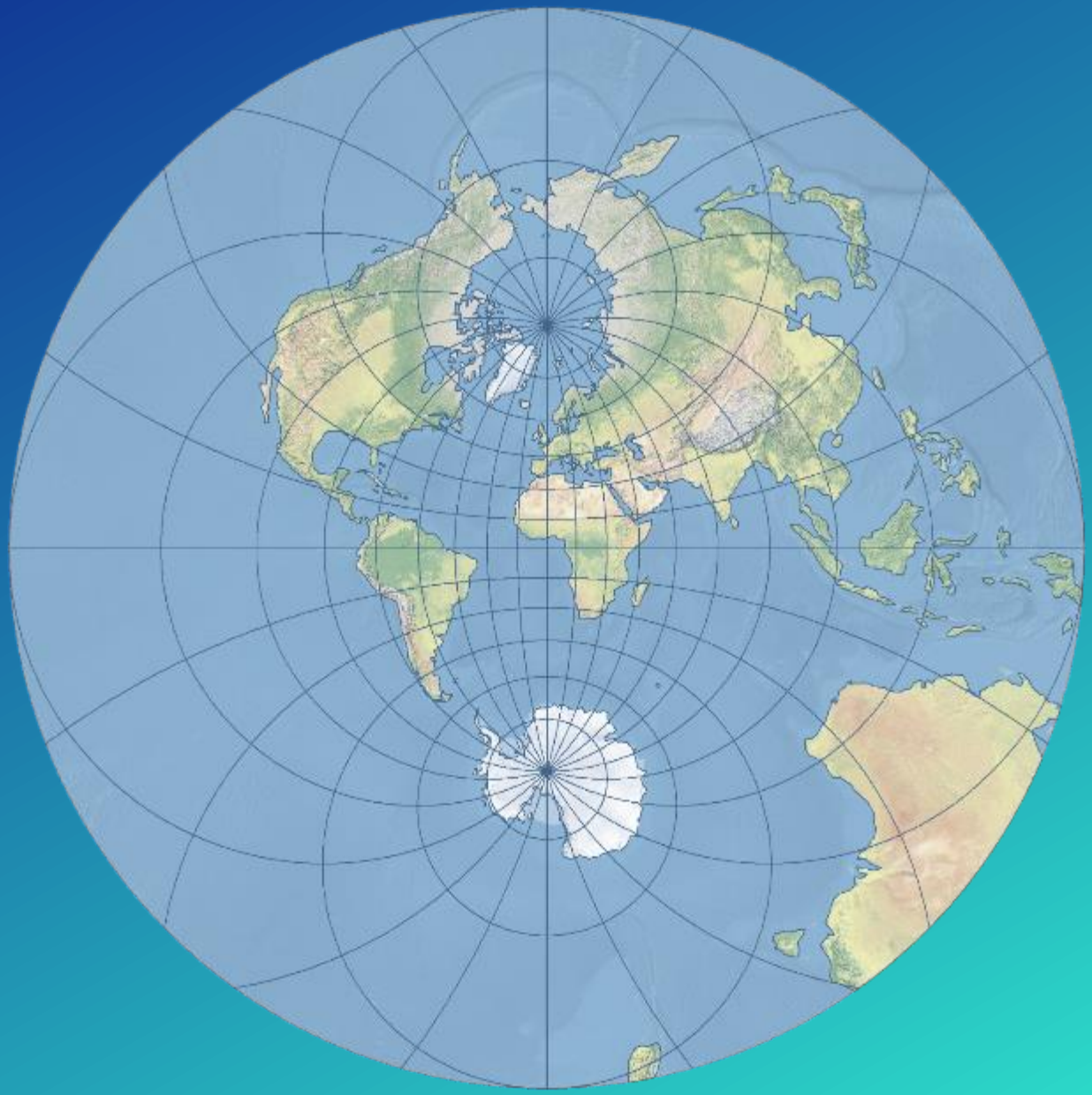
What is most important to preserve?

- Shape
- Area
- Direction
- Distance

Depends on what you are doing

Preserve Shape

- **Stereographic**

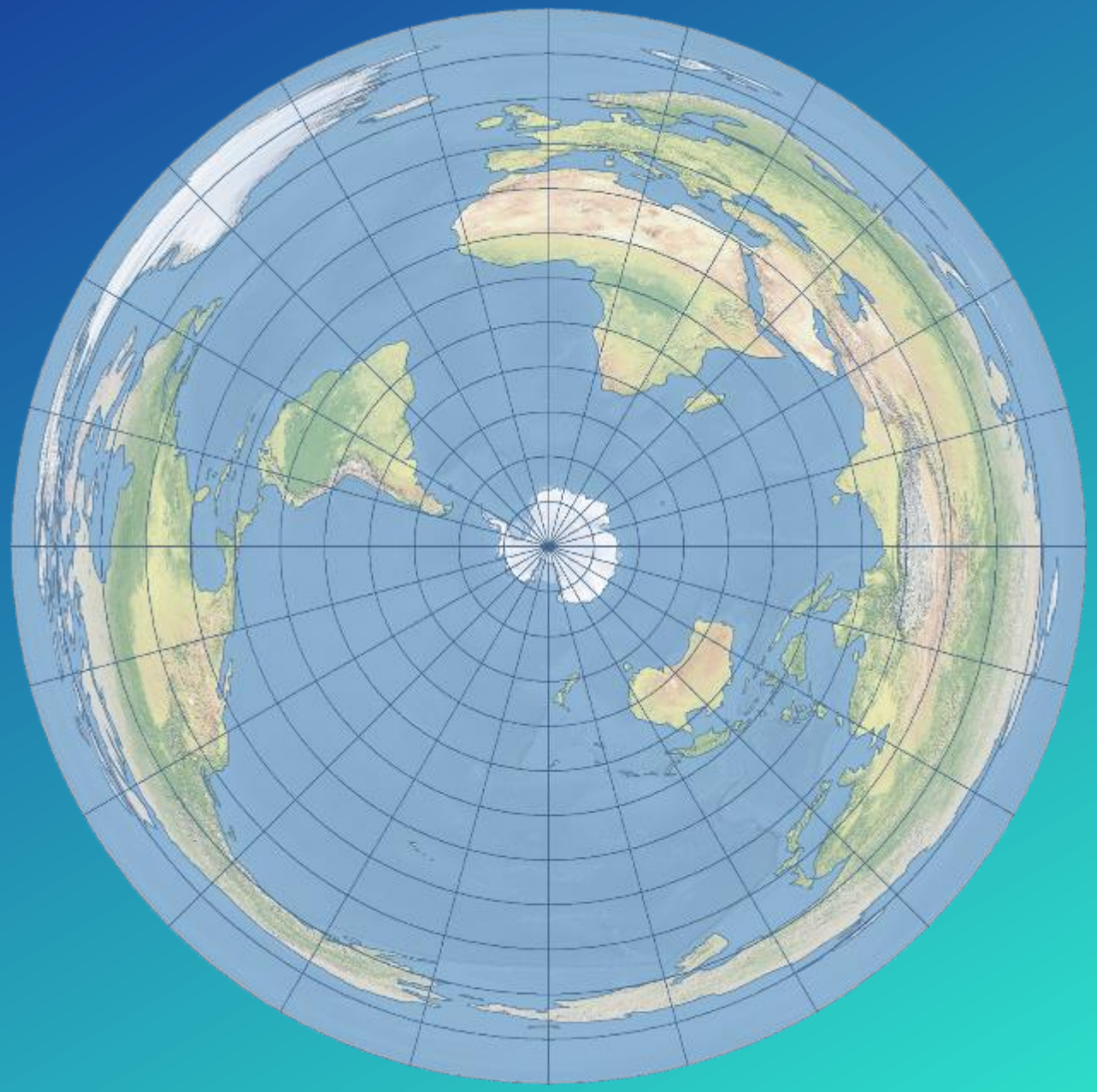


Preserve Area

- Albers equal-area conic

Preserve Direction and Distance

- Azimuthal equidistant

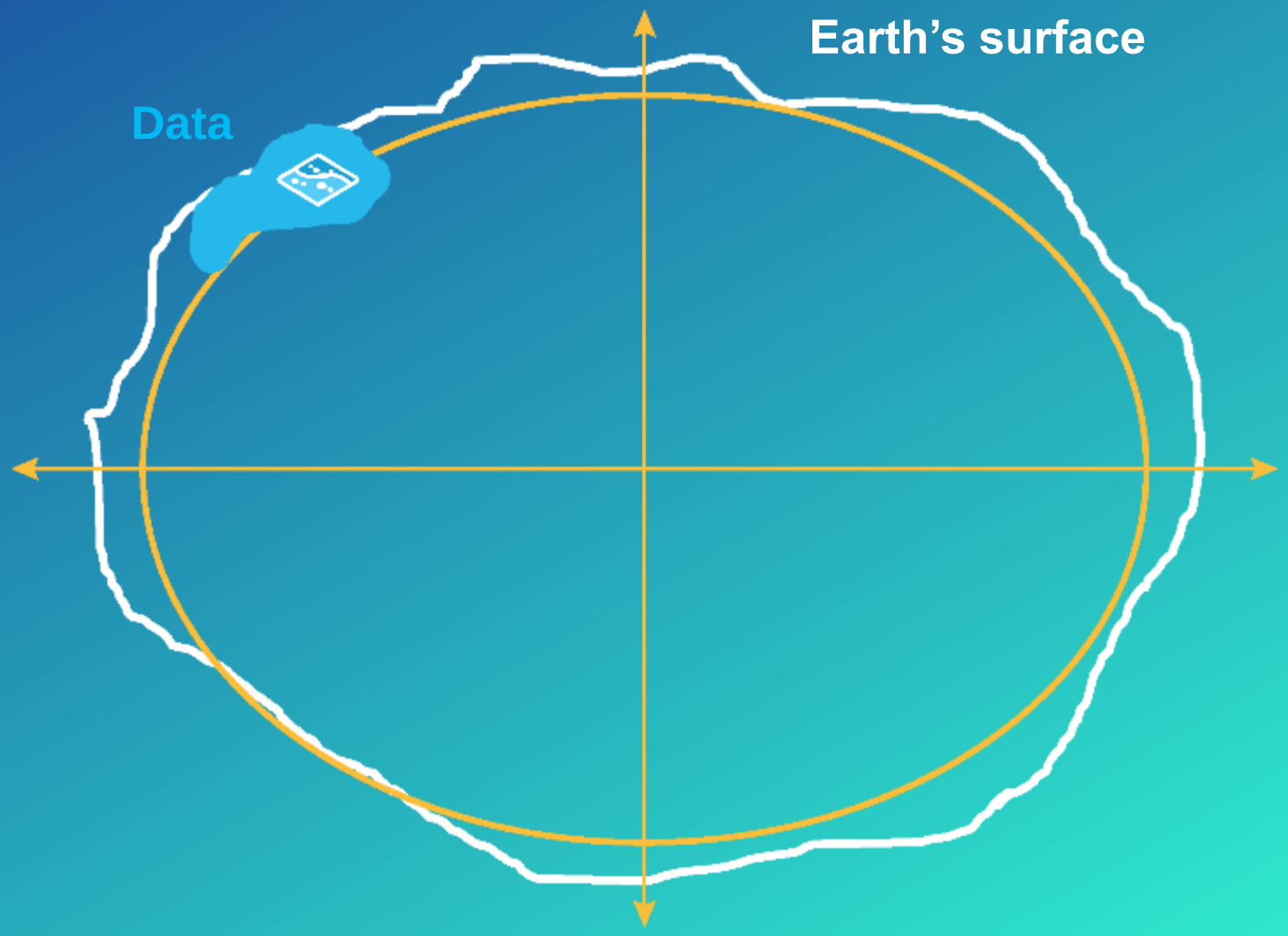


Transformations

Geographic and Vertical

Transforming Means Changing Datum

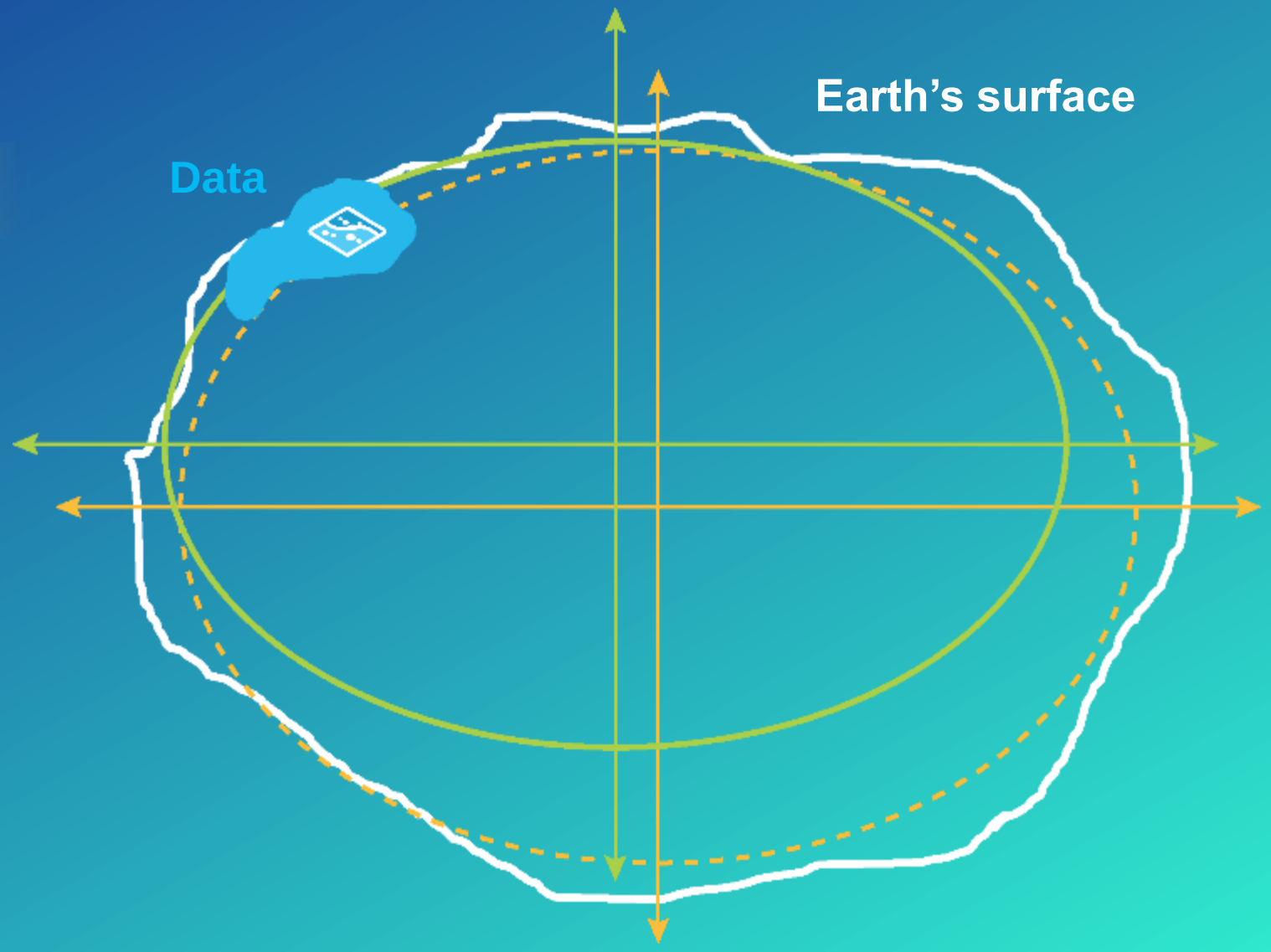
Earth-centered datum (WGS 84)



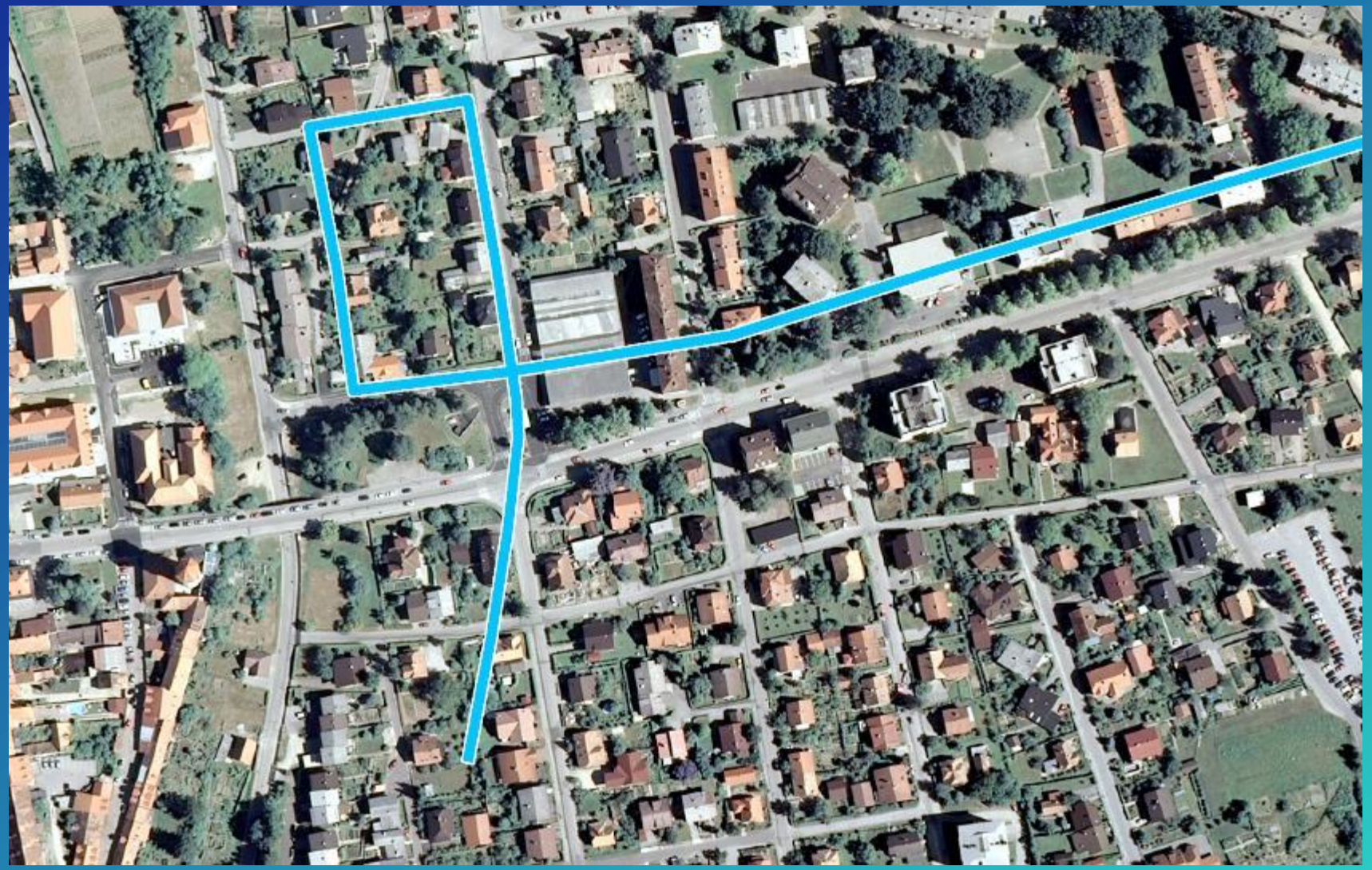
Transforming Means Changing Datum

Earth-centered datum (WGS 84)

Local datum (NAD 27)



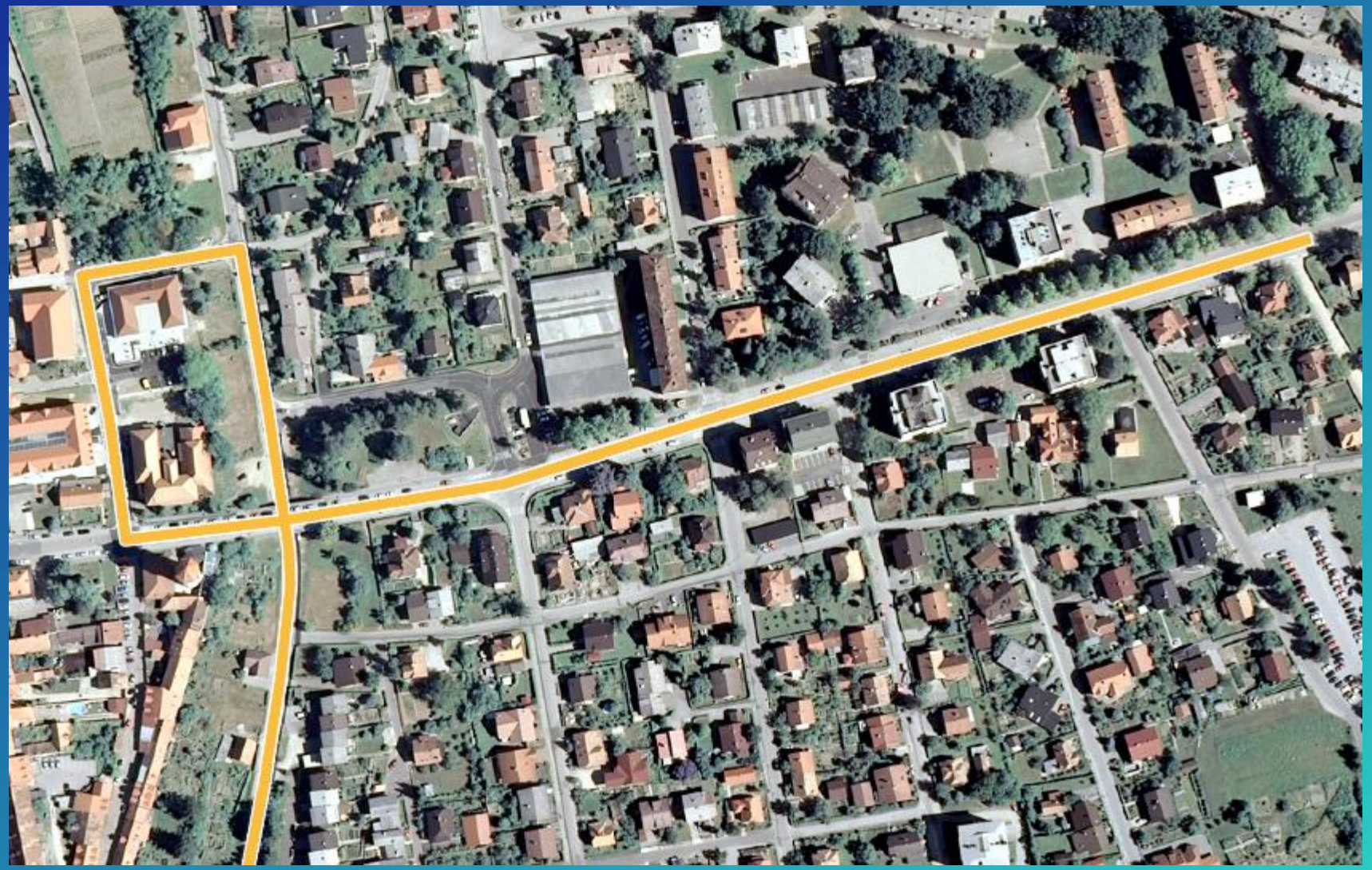
Why do we need to transform our data?



WGS 1984

ED 1950

Why do we need to transform our data?



WGS 1984

ED 1950

Two Kinds of Transformations

Geographic (datum) transformation

Vertical transformation

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

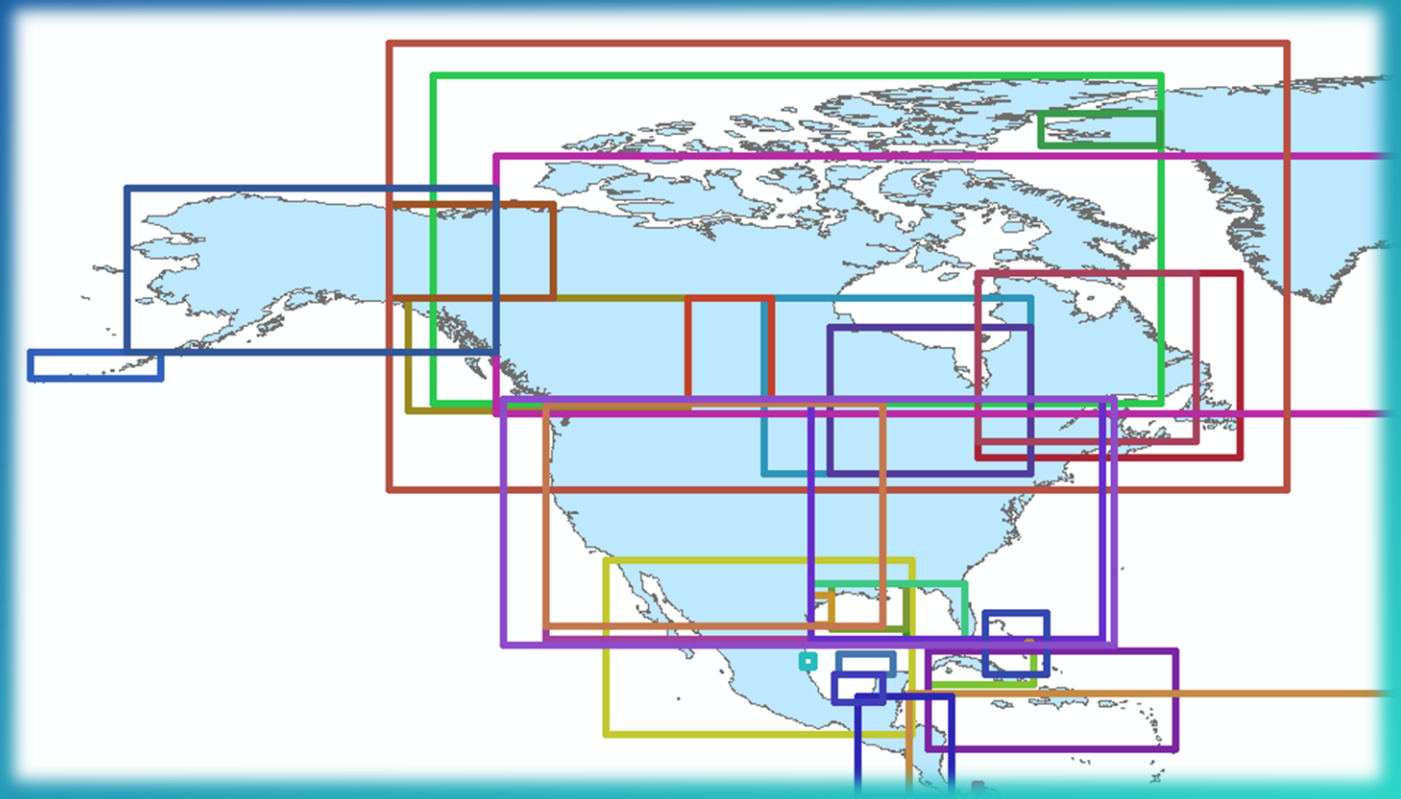
Defined for Certain Area

- **33 transformations:**

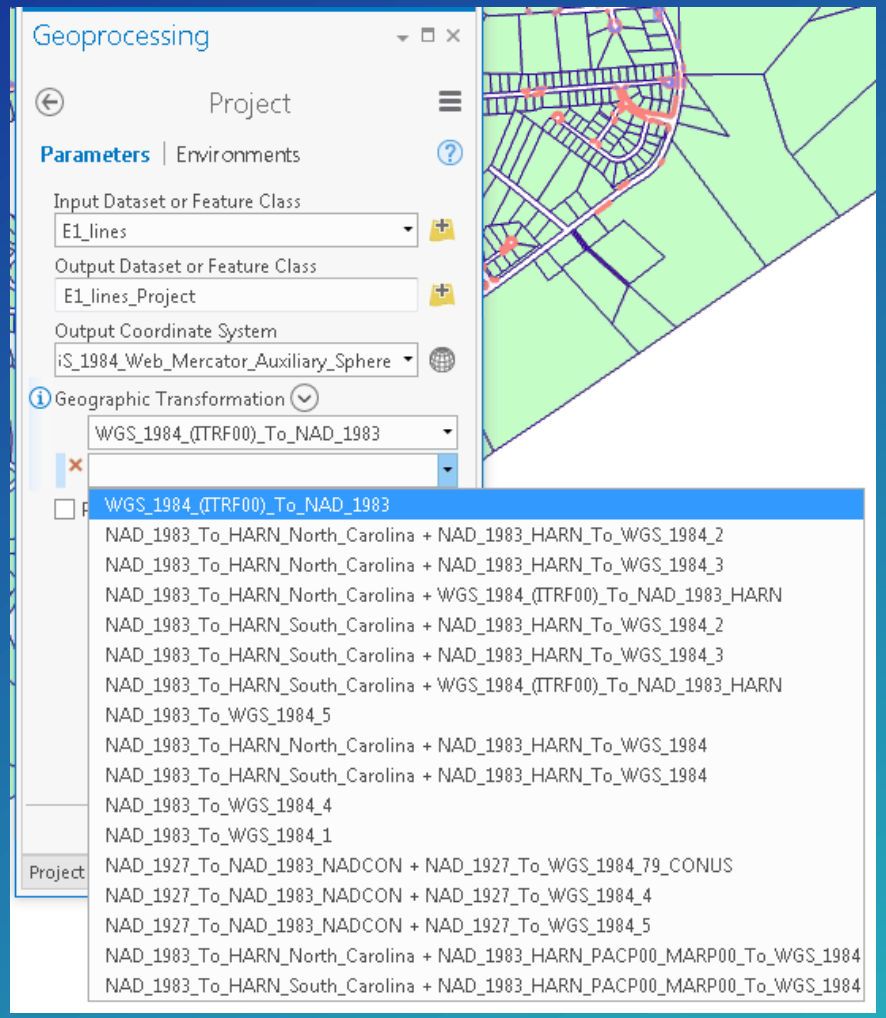
NAD 27

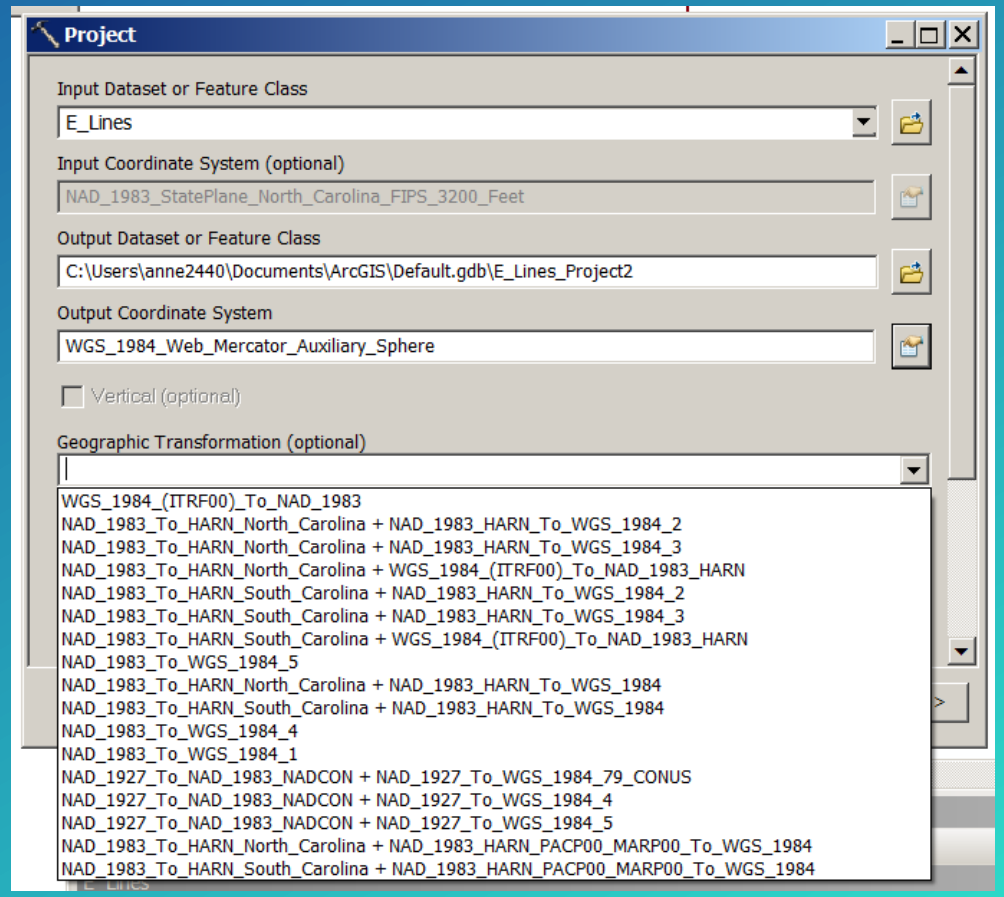
↕

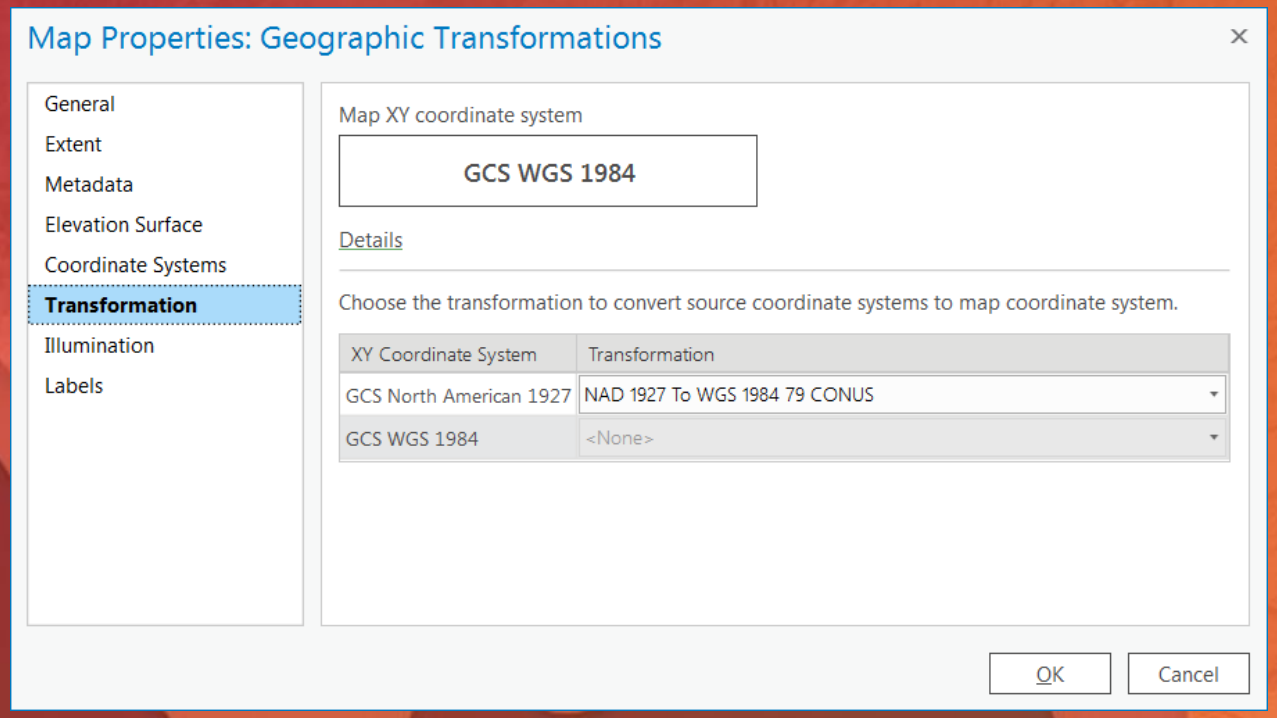
WGS 84



How do I find transformations?







Working with geographic transformations

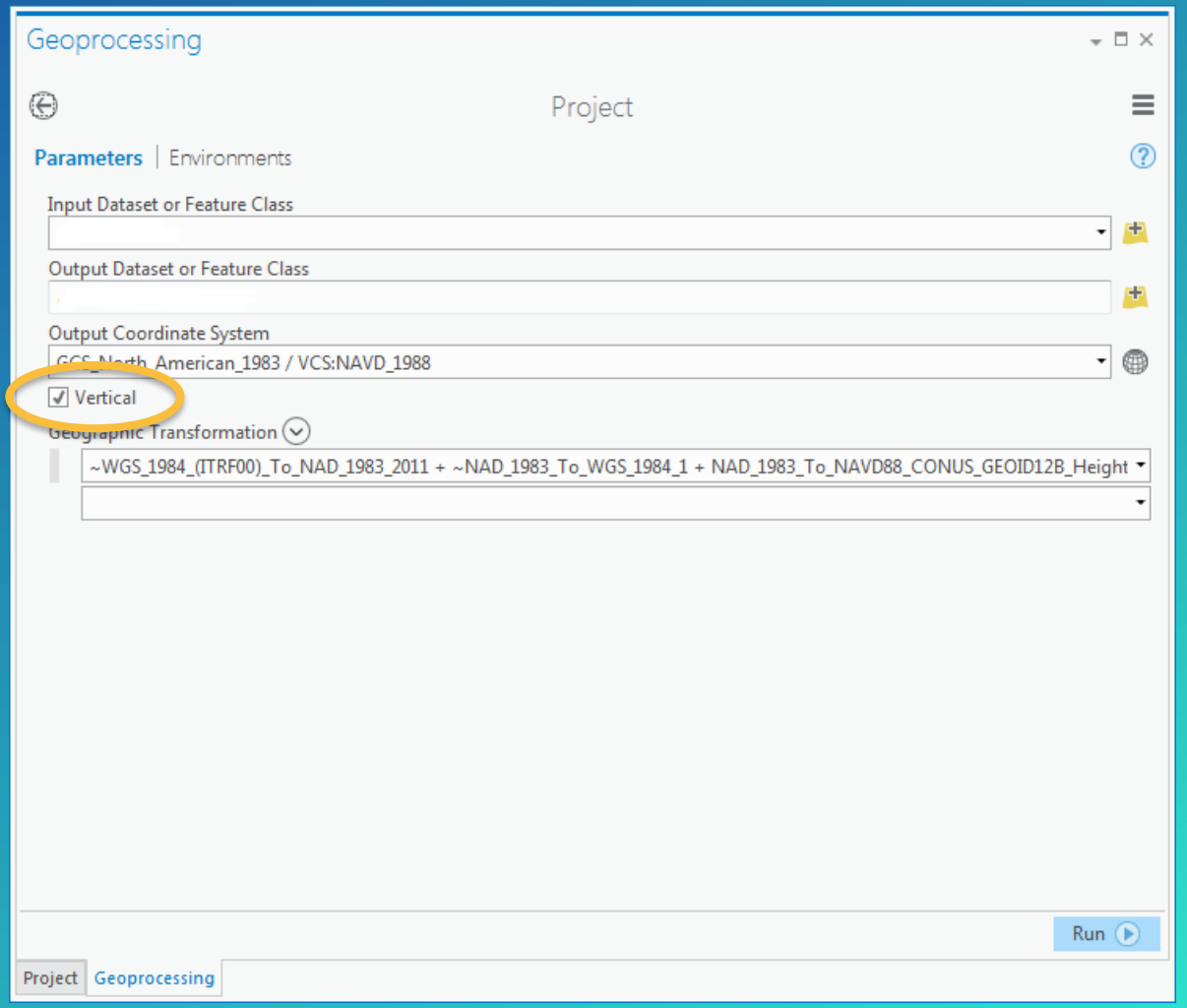
Vertical Transformation

- **New in ArcGIS 10.4 and Pro 1.4**

Ellipsoidal Heights (NAD83)

NAD_1983_To_NAVD88_
CONUS_GEOID12B_Height

Orthometric Heights (NAVD 88)



Vertical Transformation Methods

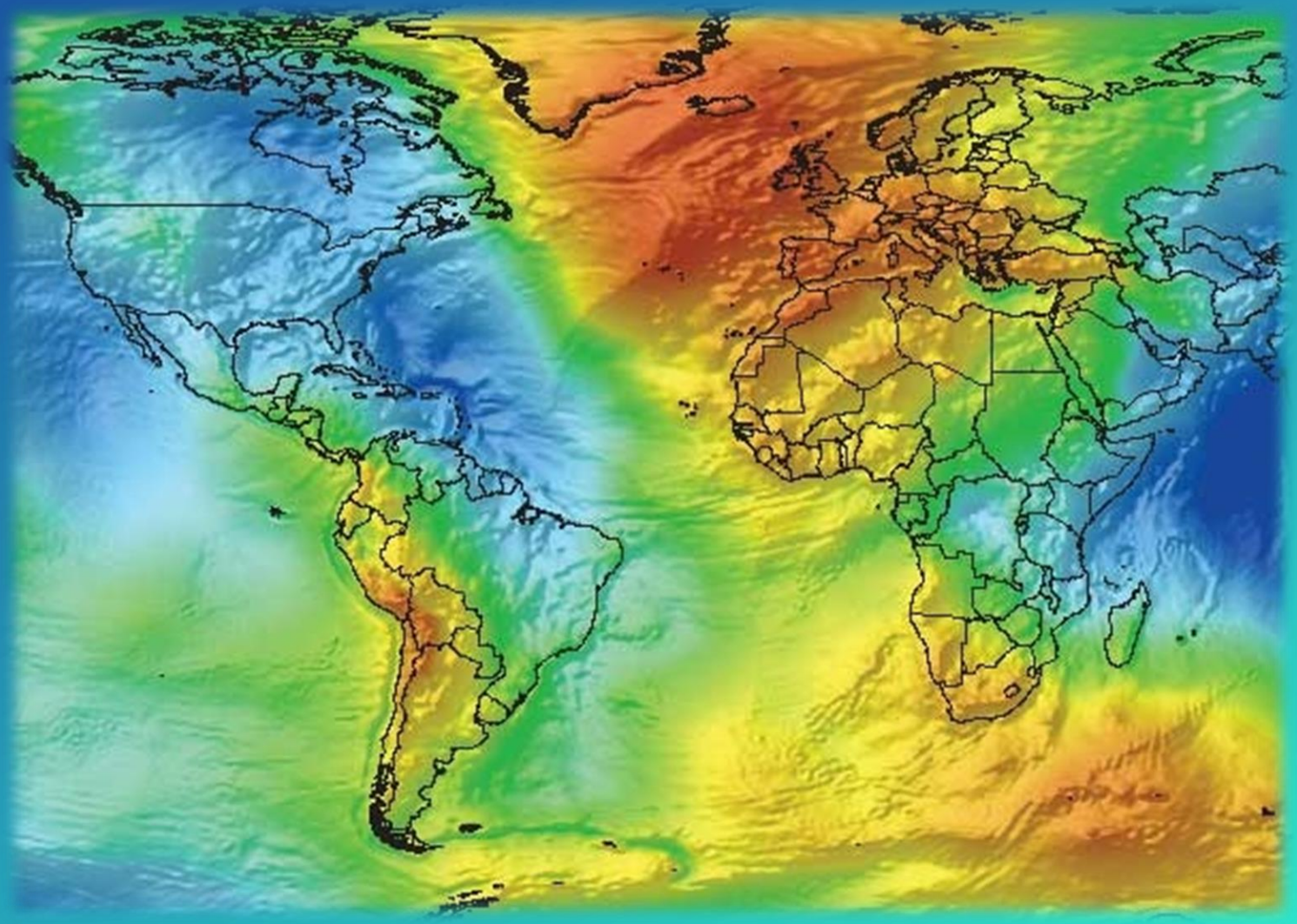
Geoid models

- EGM2008
- EGM84 and EGM96
- GEOID12B

VERTCON

Vertical offset

Vertical offset and slope



ArcGIS (Pro) Coordinate Systems Data

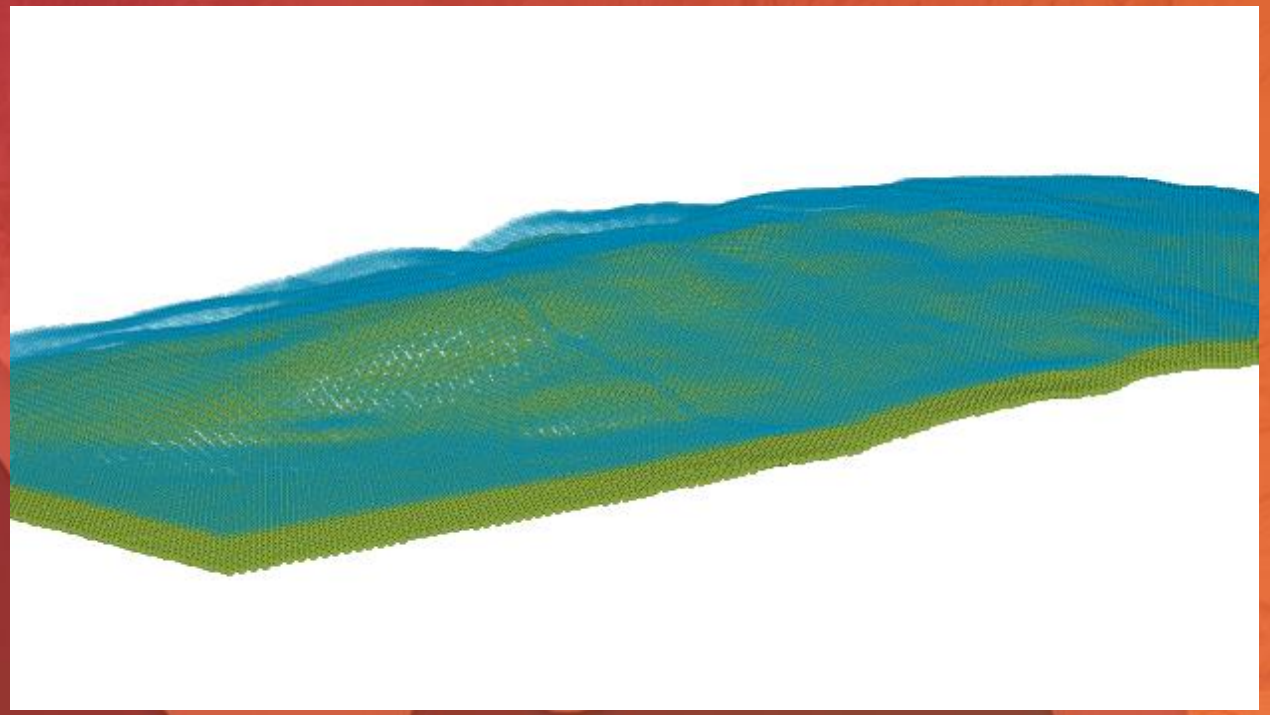
- 1.5 GB additional data install

- GEOCON v1.0
  - NAD 1983 HARN, NSRS2007, 2011
- NTv2

Geographic Transformations

- VERTCON
- GEOID12B
- EGM2008
  - 1′ x 1′ and 2.5′ x 2.5′

Vertical Transformations



Vertical transformations

Now you understand…

Projecting your data

Transforming your data

Unknown coordinate systems

Unknown coordinate systems

- ALWAYS define the coordinate system
- Good professional practice - help your successor
- Units are unknown
- Map scale is incorrect
- Geodatabase tools can’t use default values

What if I don’t know my data’s coordinate system?

- Check the data provider or source
- Check any existing metadata
- Similar data types
- What coordinate systems are used in the area?
  - http://www.epsg-registry.org
- Try using ArcMap to figure it out
  - http://esriurl.com/11518
  - *HowTo: Identify an unknown coordinate system using ArcMap*
- *Lining Up Data in ArcGIS* by Margaret Maher

Familiarize yourself with common coordinate systems

- Know what ones are used in the area
- Learn what the layer extents should be

San Diego, California		
NAD 1983	X / longitude	Y / latitude
Geographic	-116.67 °	33 °
UTM zone 11N	530,000 m	3,650,000 m
State Plane (California zone 6)	1,960,000 m	593,000 m

Where is my data?

Solution

Resources

- **Don't forget the Knowledge Base / Technical Articles!**
  - **http://esriurl.com/11518**
- **Esri forums for user-to-user help**
  - **http://geonet.esri.com**
- ***http://www.epsg.org***
  - Database of coordinate systems & datums
  - *Guidance Note 7-2*

***Lining Up Data in ArcGIS*, Margaret Maher**

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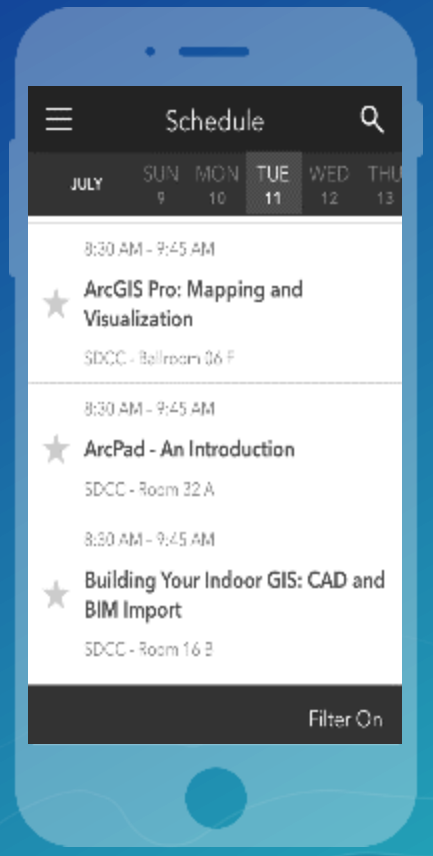
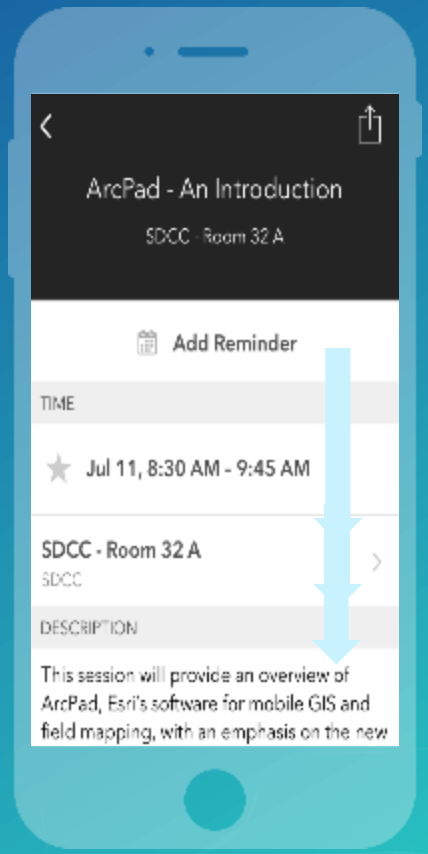
Select the session you attended



Scroll down to find the survey



Complete Answers and Select "Submit"

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THE SCIENCE OF WHERE