Satellite Data Projection and Georeferencing with Satpy

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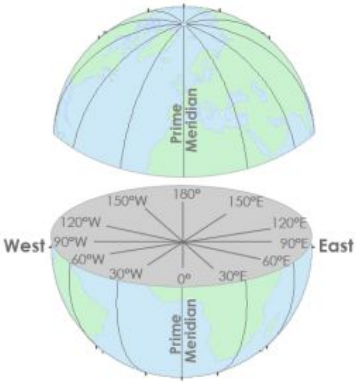
Geographic Coordinate System (GCS)

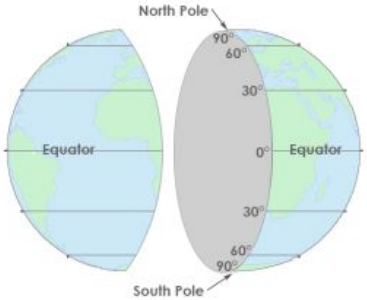
Reference framework used to identify locations on the curved surface of the Earth.

Locations are measured in angular units from the Earth's center, relative to two intersecting planes: the equatorial plane and the prime meridian plane (which passes through Greenwich, England).

Longitudes:
X-coordinates are between -180° and +180°

Latitudes:
Y-values are between -90° and +90°



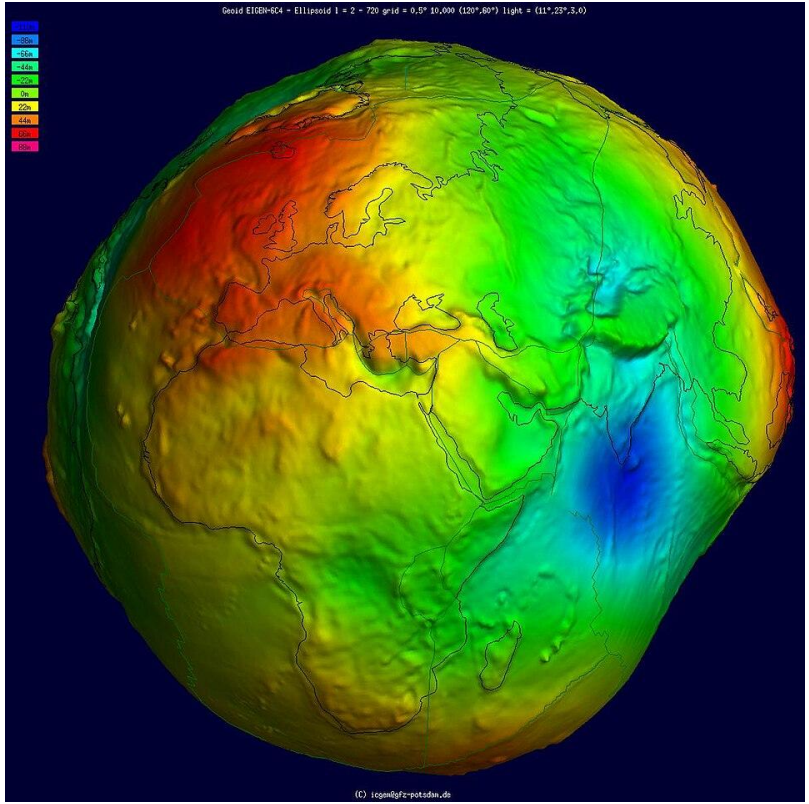


Credit: Gisgeography

Geoid

The geoid is an imaginary, uneven surface that represents mean sea level around the Earth, shaped by variations in gravity, and used as the reference for measuring elevation.

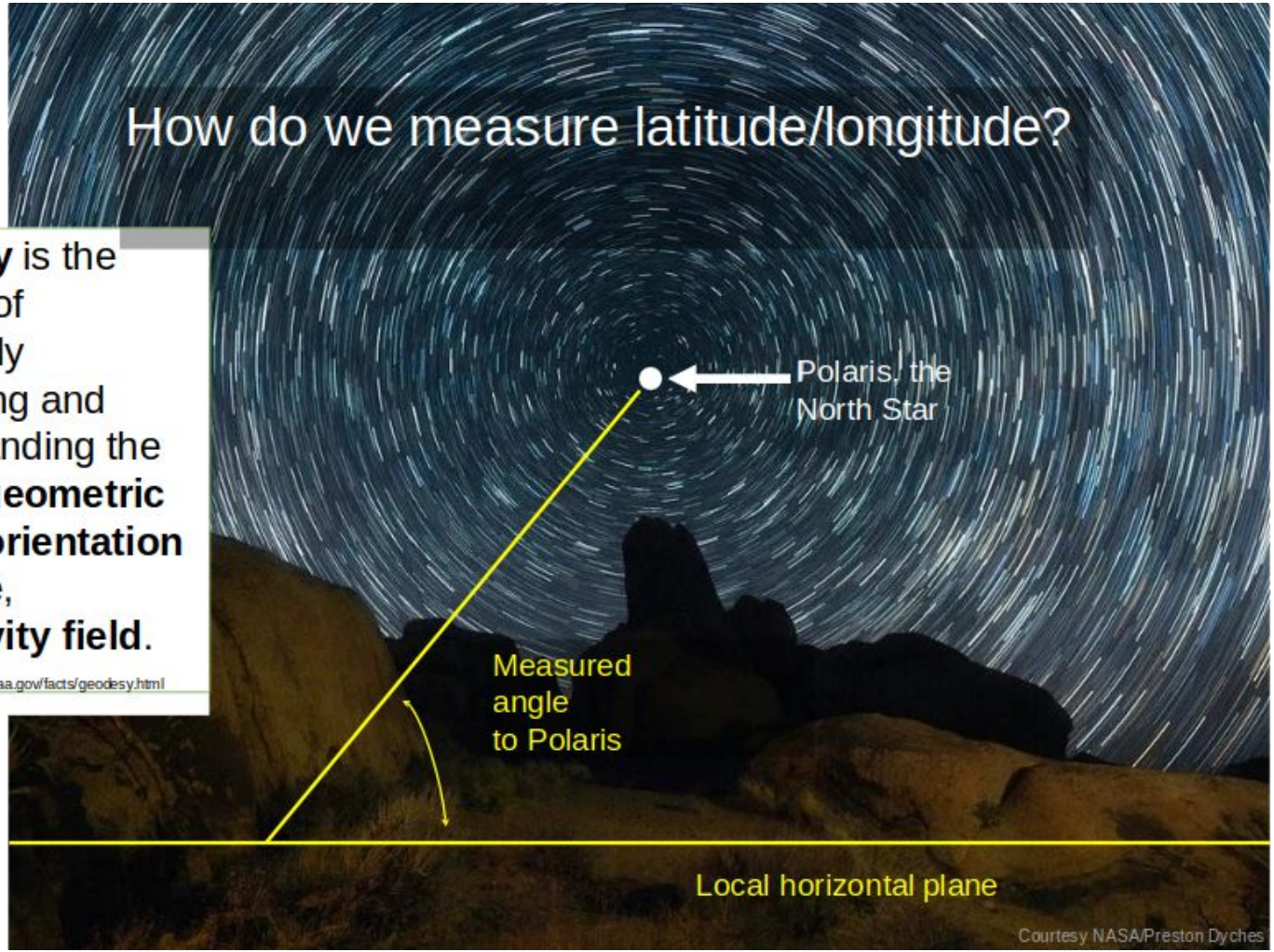
The geoid is not fixed
It slowly changes over time as Earth’s gravity field changes due to moving mass.



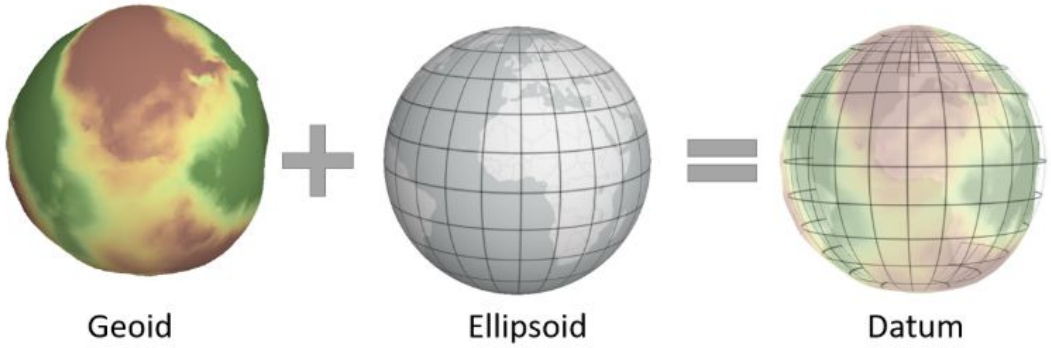
How do we measure latitude/longitude?

Geodesy is the science of accurately measuring and understanding the Earth's **geometric shape**, **orientation in space**, and **gravity field**.

https://oceanservice.noaa.gov/facts/geodesy.html



Datum



Credit: mgimond

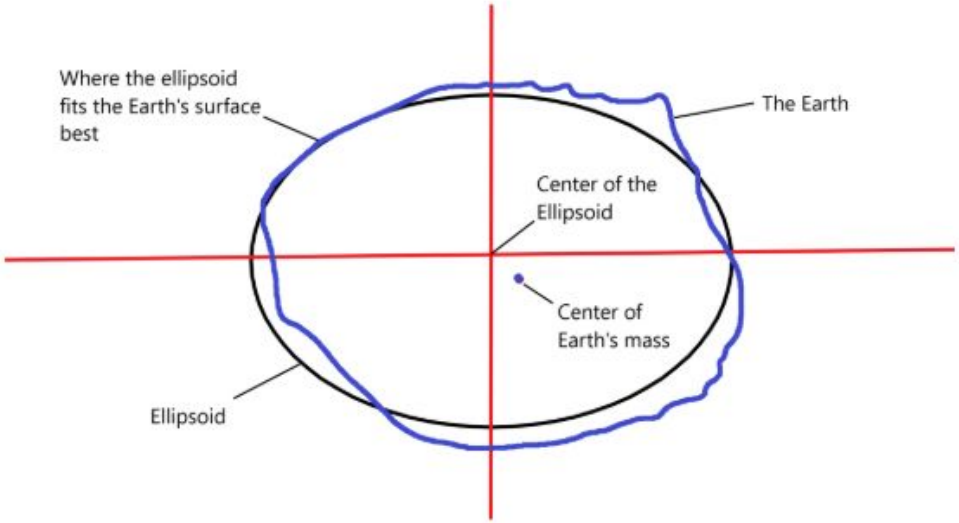
A datum allows us to map the Earth's surface features onto an ellipsoid

It defines where "zero" is in spatial data

Inaccurate or mismatched datums = **wrong locations**.

There are two main datums in the United States. **Horizontal datums** measure positions (latitude and longitude) on the surface of the Earth, while **vertical datums** are used to measure land elevations and water depths.

Horizontal datum

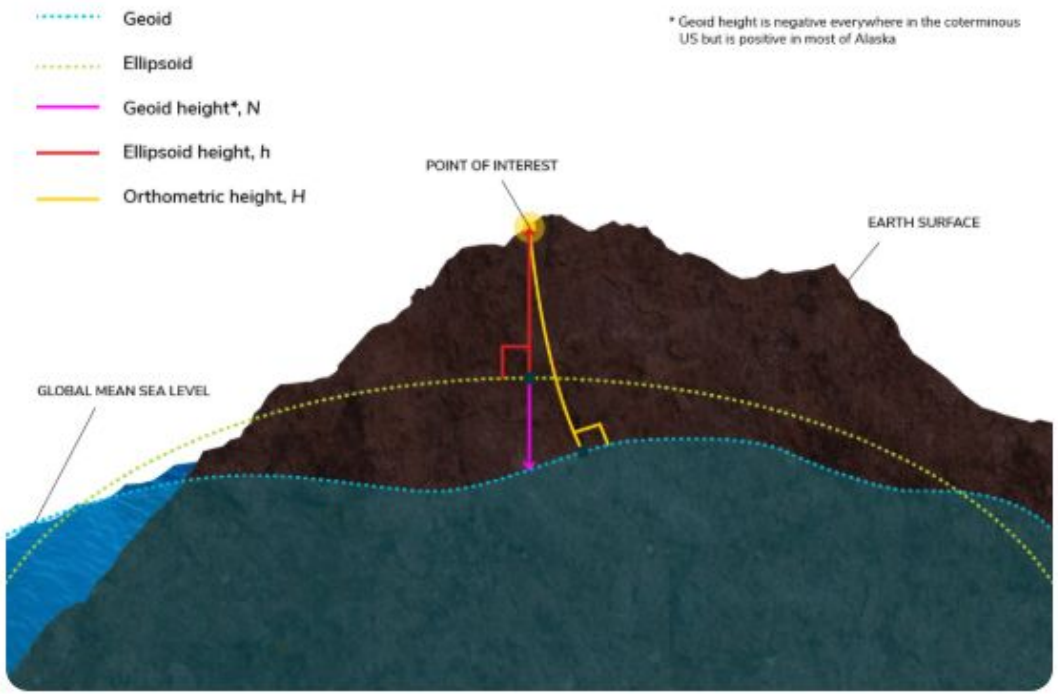


Horizontal datums take an ellipsoid and assign its center a point of origin relative to the center of the earth.

Credit: mgimond

Vertical datum

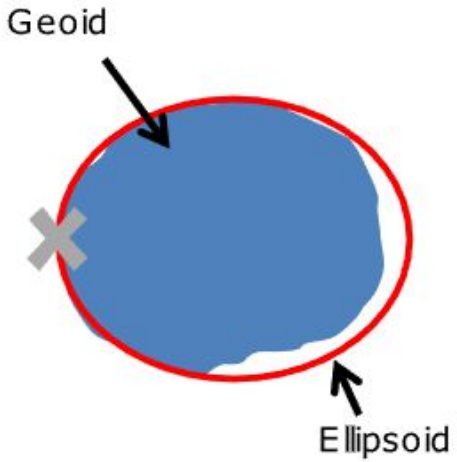
How low (or high) can you go?



Credit: Propeller

Local datum vs Geocentric datum

Local datum



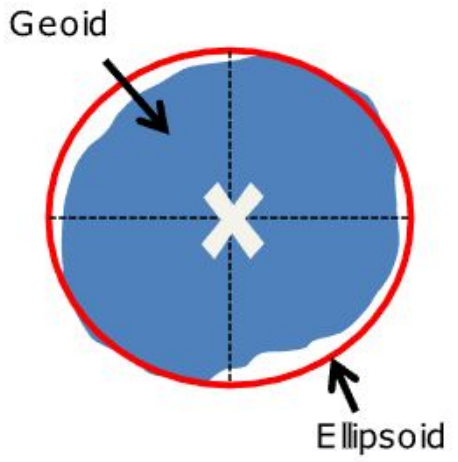
designed to fit the **Earth's surface in a specific region**

-NAD27 (North American Datum 1927)

-ED50 (European Datum of 1950)

-Arc 1960 (East Africa)

Geocentric datum



designed to fit the **Earth's center of mass (geocenter)**

-NAD83 (North American Datum of 1983)

-ETRS89 (European Terrestrial Reference System 1989)

-WGS84 (World Geodetic System 1984)

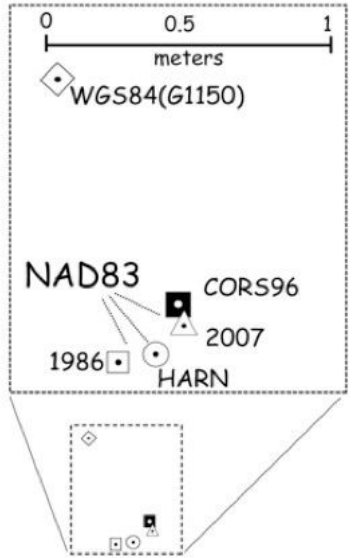
Credit: mgimond

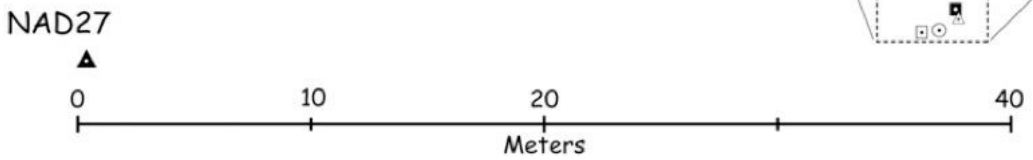
Datums change through time

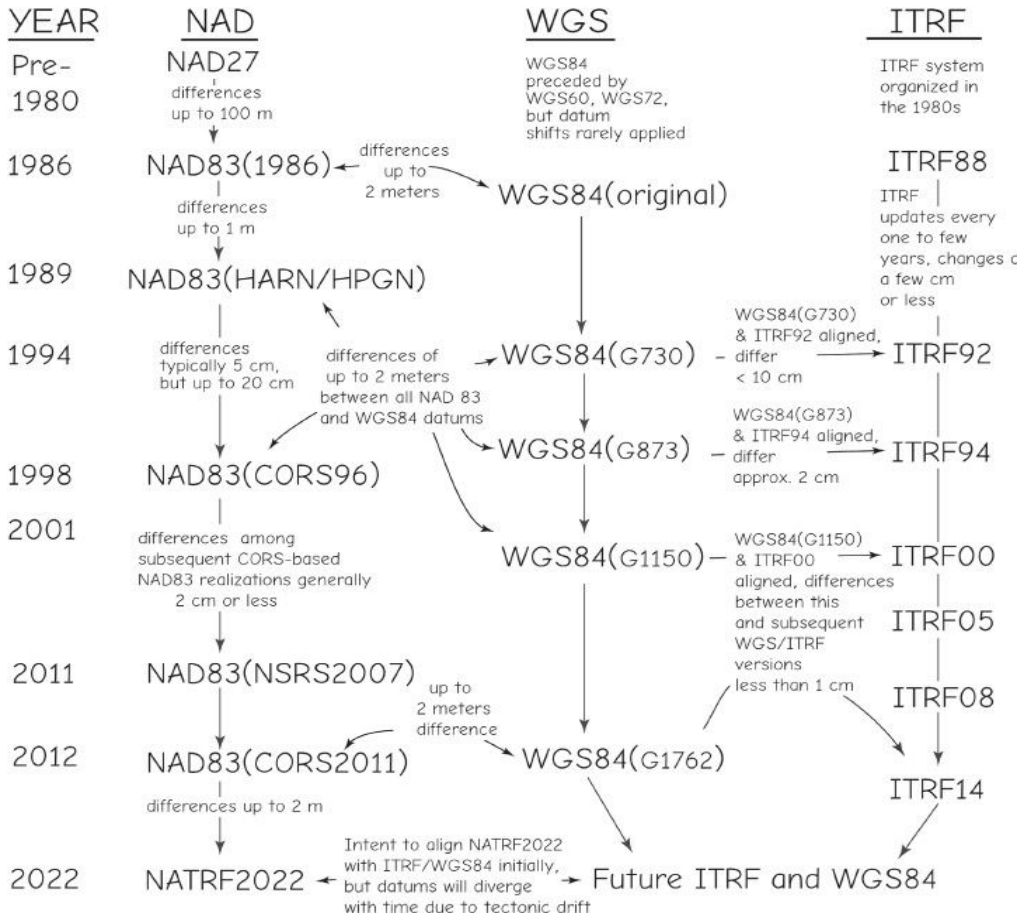
Examples of Datum Shifts

Successive datum transformations for New Jersey control point, Bloom 1

Datum	Longitude (W)	Latitude(N)	Shift(m)
NAD27	74° 12' 3.86927"	40° 47' 0.76531"	36.3
NAD83(1986)	74° 12' 2.39240"	40° 47' 1.12726"	0.04
NAD83(HARN)	74° 12' 2.39069"	40° 47' 1.12762"	0.05
NAD83(CORS96)	74° 12' 2.39009"	40° 47' 1.12936"	0.01
NAD83(2007)	74° 12' 2.38977"	40° 47' 1.12912"	0.95
WGS84(G1150)	74° 12' 2.39720"	40° 47' 1.15946"	



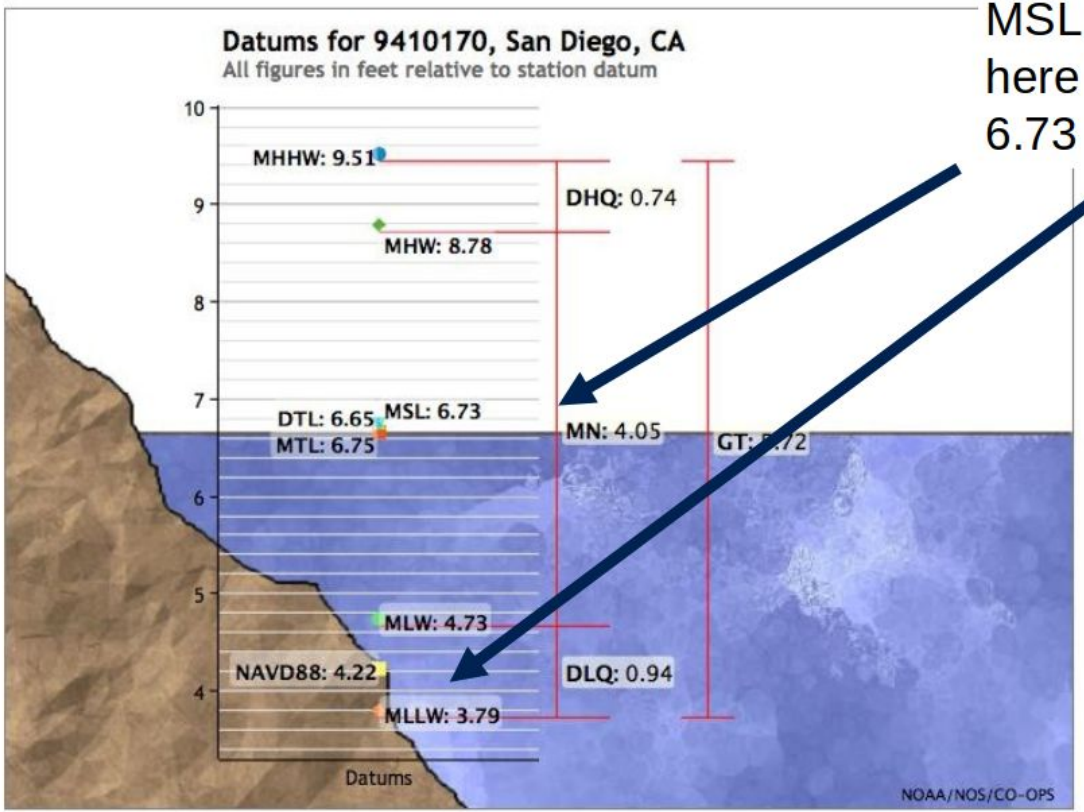




Source: Bolstad, P. (2019). GIS fundamentals, 6th Edition, Livonia, MI, XanEdu Publishing Inc

Tidal gauge sites

Difference between MSL and NAVD88, here 2.51 ft, 6.73 - 4.22

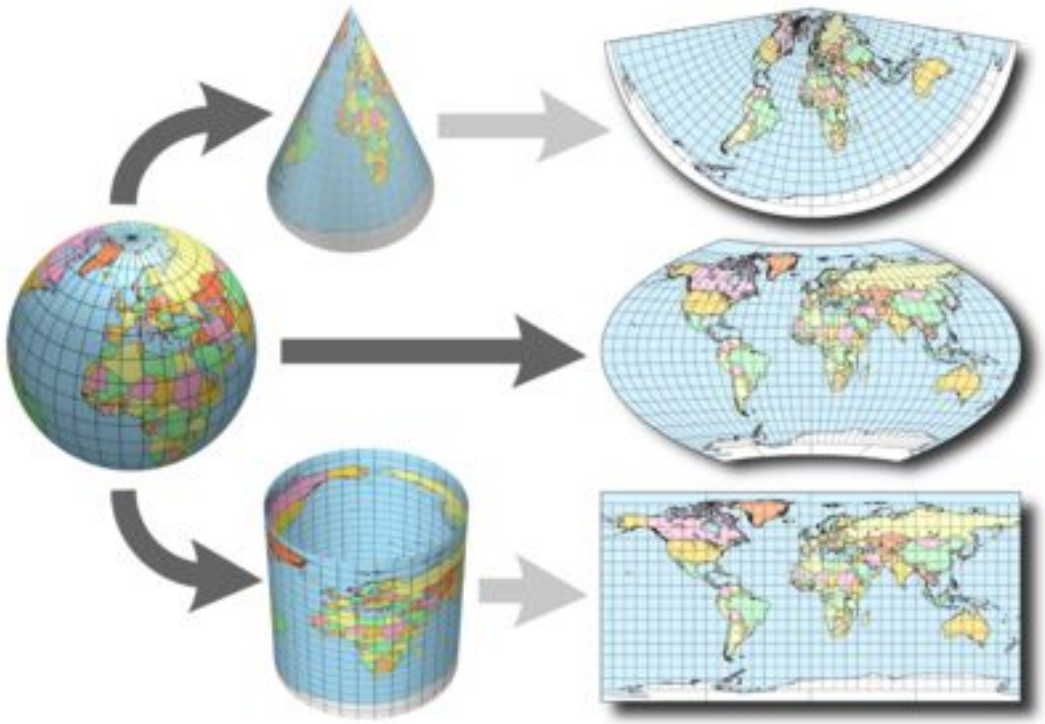


https://tidesandcurrents.noaa.gov/datums.html?id=9410170

Source: Bolstad, P. (2019). GIS fundamentals, 6th Edition, Livonia, MI, XanEdu Publishing Inc

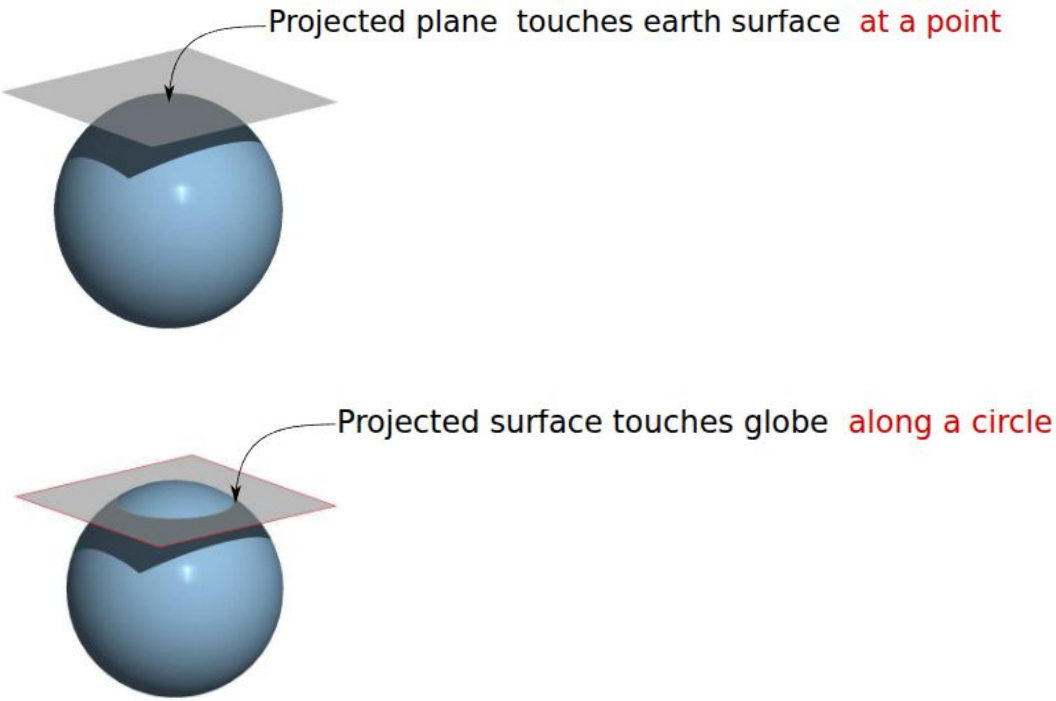
Projected Coordinate Systems

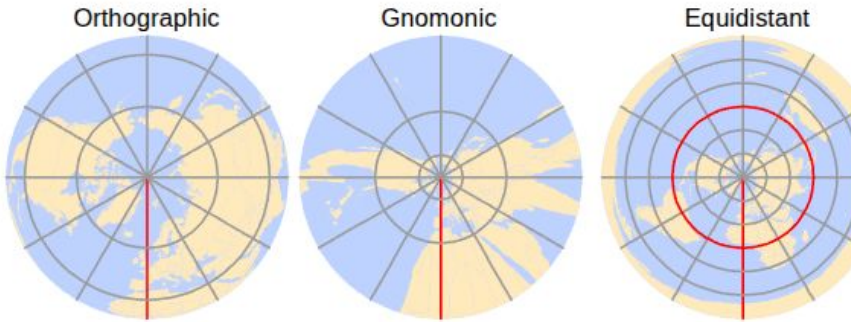
Spatial projection refers to the mathematical calculations performed to flatten the 3D data onto a 2D plane



Projected Coordinate Systems

Planar projection



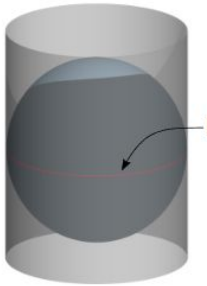


Examples of three planar projections

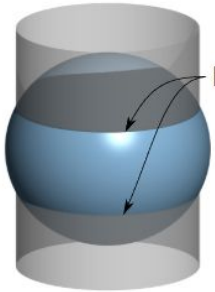
Source: mgimond

Projected Coordinate Systems

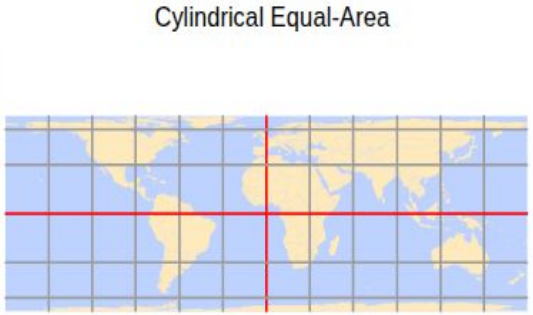
Cylindrical projections



Projected plane touches earth surface along one circle



Projected plane touches earth surface along two circles

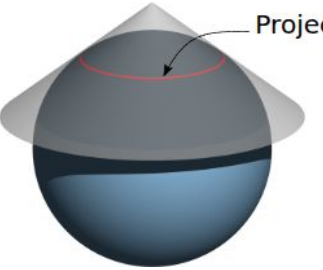


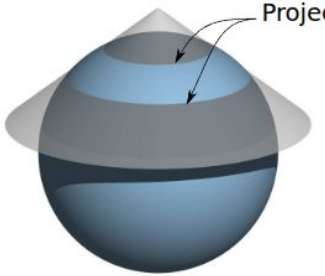
Examples of two cylindrical projections

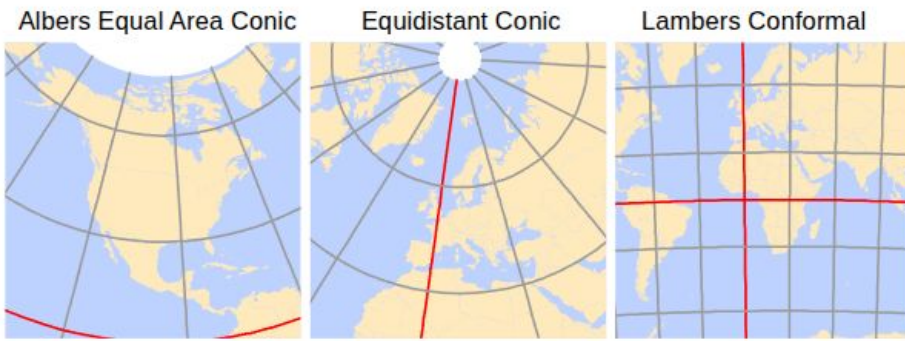
Source: mgimond

Projected Coordinate Systems

Conical Projection

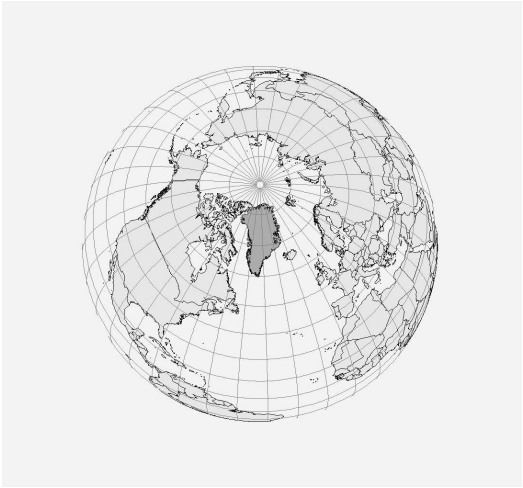


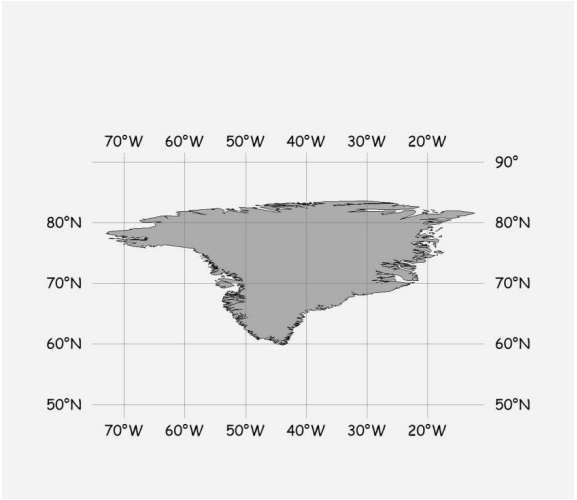


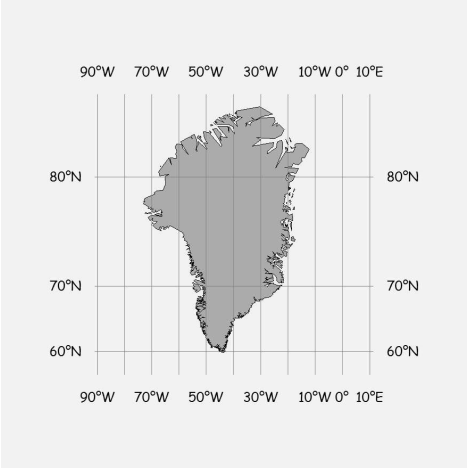


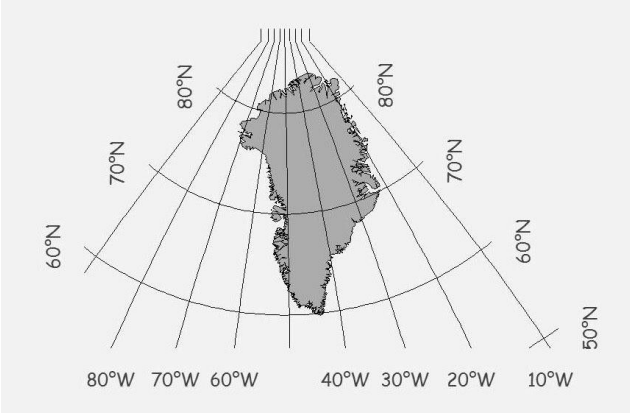
Examples of three conical projections

Source: mgimond









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Common coordinate projections

Projection Name	Type	Units	Region / Zone	Preserves	Used For	Strengths
UTM (Universal Transverse Mercator)	Cylindrical (Transverse)	Meters	Global (60 zones, 6° wide)	Shape, distance (locally)	Regional maps, GPS, engineering	High local accuracy; easy to use; metric units
SPCS (State Plane Coordinate System)	Varies by state (Lambert or Transverse)	Meters or Feet	USA (state-level zones)	Shape, distance	Surveying, land parcels, utilities in U.S.	Extremely accurate locally; designed for legal boundaries
Web Mercator (EPSG:3857)	Pseudo-Cylindrical (Mercator)	Meters	Global (mainly online)	Shape	Web maps (Google, Bing, OSM, Leaflet)	Fast rendering; widely supported for tile services
Lambert Conformal Conic	Conic	Meters	Mid-latitudes (e.g. Europe, U.S.)	Shape	Weather maps, aviation, national/regional maps	Accurate along standard parallels; good for E-W areas
Albers Equal Area Conic	Conic (Equal Area)	Meters	North America, global thematic	Area	Population, land cover, climate mapping	Best for preserving area; useful for thematic data

Satpy

Open-source Python library for reading, processing, and visualizing satellite data, developed by the Pytroll community and used operationally by NOAA, EUMETSAT, and meteorological services worldwide.

- Reads 70+ satellite file formats automatically
- Calibrates raw sensor counts to physical units
- Builds RGB composites (true color, false color, microphysics)
- Resamples swath data onto any map projection
- Saves to GeoTIFF, NetCDF, PNG, and more

Supported Satellites

Geostationary — full disk, refreshed every few minutes

Satellite	Instrument	Agency	Region
GOES-16/18/19	ABI	NOAA	Americas
Meteosat MSG/MTG	SEVIRI / FCI	EUMETSAT	Europe & Africa
Himawari-8/9	AHI	JMA	Asia & Pacific
GEO-KOMPSAT-2A	AMI	KMA	Korea
FY-4A/B	AGRI	CMA	China

Polar-orbiting — global coverage, higher resolution

Satellite	Instrument	Agency
Suomi-NPP / NOAA-20 / NOAA-21	VIIRS	NOAA
Terra / Aqua	MODIS	NASA
MetOp	AVHRR / IASI	EUMETSAT
Sentinel-1/2/3	SAR / MSI / OLCI	ESA

THANK YOU

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