CE-317 GIS/RS Application to Civil Engineering
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•Engr. Faisal ur Rehman

•Lecture 03: Coordinate Systems

Datums

- Datums: Datums define the reference systems that describe the size and shape of the earth
- It defines the origin and orientation of the coordinate systems used to map the earth.

Datum

- Modern geodetic datums range from flat-earth models used for plane surveying to complex models used for international applications
- Which completely describe the size shape, orientation, gravity field, and angular velocity of the earth.

Datum

- Geodetic datums and the coordinate reference systems based on them were developed to describe geographic positions for surveying, mapping, and navigation.
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Shape of Earth

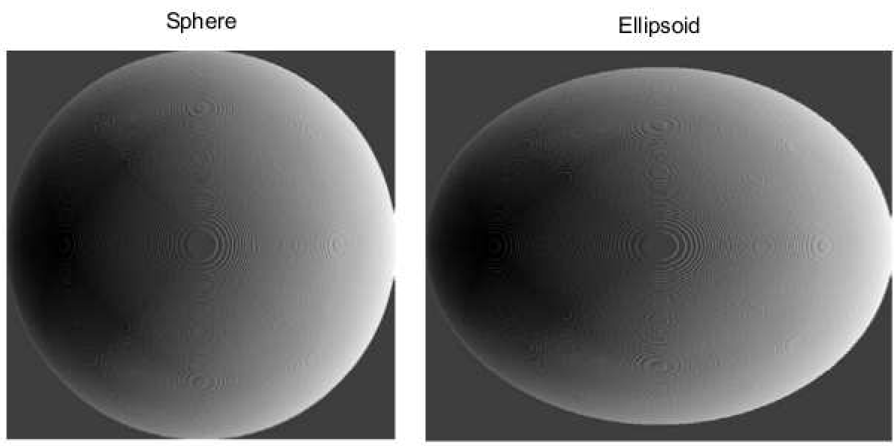

Figure 3.3: Earth shape: sphere or ellipsoid.

Datum Types

1. Horizontal: Datums that define the relationship between the physical earth and horizontal coordinates such as latitude and longitude.

- Examples include the North American Datum of 1927 (NAD27) and the European Datum 1950 (ED50).

Datum Types

2. Vertical: Datums that define level surfaces.

- Examples include the National Geodetic Vertical Datum of 1929 (NGVD29) and the North American Vertical Datum of 1988 (NAVD88).
- Some are based on sea-level measurements and levelling networks (NGVD29), others on gravity measurements (NAVD88).

Datum Types

3. Complete: Datums that describe both vertical and horizontal systems. Some, such as World Geodetic System 1984 (WGS-84)

- also describe other parameters such as the rotation rate of the earth
- and various physical constants such as the angular velocity of the earth and the earth's gravitational constant.

Reference Ellipsoids

- Reference ellipsoids are defined by either semi-major (equatorial radius) and semi-minor (polar radius) axes, or the relationship between the semi-major axis and the flattening of the ellipsoid (expressed as its eccentricity).
- Many reference ellipsoids are in use by different nations and agencies.
- Reference ellipsoids are identified by a name and often by a year for example, the Clarke 1866 ellipsoid is different from the Clarke 1858 and the Clarke 1880 ellipsoids.

Geodetic Datums

- Precise positioning must also account for irregularities in the earth's surface due to factors in addition to polar flattening.
- Topographic and sea-level models attempt to model the physical variations of the surface:
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Geodetic Datums

- The topographic surface of the earth is the actual surface of the land and sea at some moment in time.
    - Aircraft navigators have a special interest in maintaining a positive height vector above this surface.
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Geodetic Datums

- Sea level can be thought of as the average surface of the oceans, though its true definition is far more complex.
    - Specific methods for determining sea level and the temporal spans used in these calculations vary considerably.
    - Tidal forces and gravity differences from location to location cause even this smoothed surface to vary over the globe by hundreds of meters.

GEOID

- Gravity models and geoids are used to represent local variations in gravity that change the local definition of a level surface.
- Gravity models attempt to describe in detail the variations in the gravity field.
- The importance of this effort is related to the idea of levelling.
- Plane and geodetic surveying uses the idea of a plane perpendicular to the gravity surface of the earth

GEOID

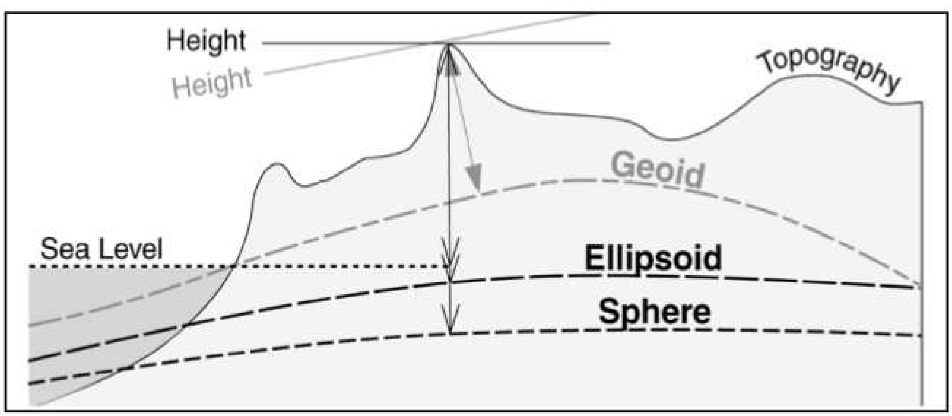

Figure 3.4: Elevations defined with reference to a sphere, ellipsoid, geoid, or local sea level will all be different. Even location as latitude and longitude will vary somewhat.

Reference System

- Global systems can refer to positions over much of the Earth.
- Regional systems have been defined for many specific areas, often covering national, state, or provincial areas.

General Coordinate Systems

- Plane
- Global

Plane Coordinate System

Plane coordinate system – Cartesian coordinates: Cartesian coordinates are determined by locating an origin there after setting two axes through origin in fixed directions, at right angles to each other.

- By convention these are usually identified as x and y, where x is horizontal and y vertical (x is east, y is north).
- To measure linear displacement from the origin in directions defined by the two axes produces an ordered (x, y) pairs.

Storing Coordinates

- Integer vs real numbers:
  - The number is the product (a × 10b), e.g., +1234 +2 would indicate 0.1234 × 102 or 12.34.

Storing Coordinates

- Computer precision: In the computer, the number of digits which can be stored for each value is limited by the hardware, integers are normally stored using 16 bits of memory and can have a range from – 32767 to +32767.
- Floating point numbers can use single or double precision.
- Single precision commonly allocates 32 bits, or 4 bytes, of memory for each value, equivalent to 7 significant decimal digits

Plane Coordinate System

- Plane coordinate system – Polar coordinates: Polar coordinates use distance from origin (r) and angle from fixed direction (q), usually fixed direction is north and angle is measured clockwise from it.
- Polar coordinates are useful for measuring from some fixed point such as the center of the city or when using data from sources such as ground surveys and radar.
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To translate from (r, q) to (x,y)

- ???

Earth Coordinate Geometry

- The earth's spherical shape is more difficult to describe than a plane surface.
- Concepts from Cartesian coordinate geometry have been incorporated into the earth's coordinate system.
- Rotation of the Earth: The spinning of the earth on its imaginary axis is called rotation.
- The spinning has led to the creation of a system to determine points and directions on the sphere.
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Earth Coordinate Geometry

- If the North Pole was extended, it would point to a fixed star, the North Star (Polaris).
- Any point on the earth's surface moves with the rotation and traces imaginary curved lines are Parallel of Latitude.
- The Equator: If a plane bisected the earth midway between the axis of rotation and perpendicular to it, the intersection with the surface would form a circle.
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Earth Coordinate Geometry

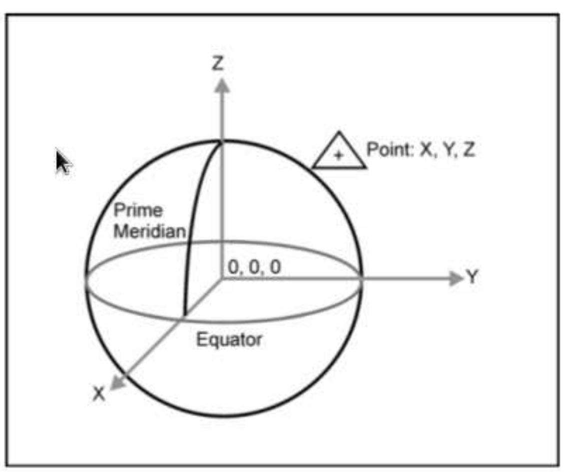

Figure 3.6: Earth Centered, Earth Fixed (ECEF) Cartesian coordinates can also be used to define three dimensional positions.

Earth Coordinate Geometry

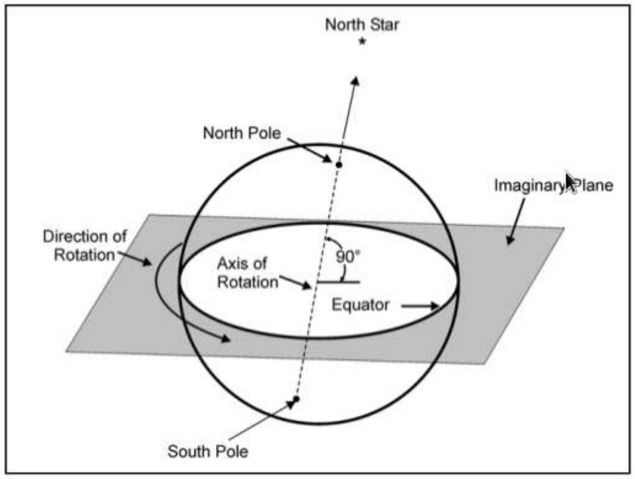

Figure 3.7: Location of the equator, north and south poles, and the imaginary axis of rotation.

The Geographic Grid

- The Geographic Grid: The spherical coordinate system with latitudes and longitudes used for determining the locations of surface features.
  - Parallels: east-west lines parallel to the equator.
  - Meridians: north-south lines connecting the poles.
  - Parallels are constantly parallel, and meridians converge at the poles.
  - Meridians and parallels always intersect at right angles.

The Geographic Grid

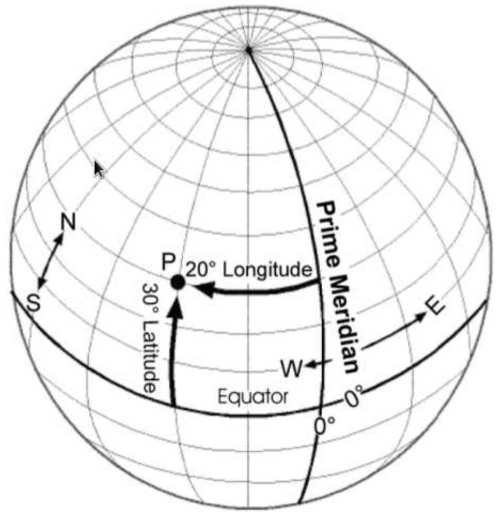

Figure 3.8: The Geographic grid.

The Geographic Grid

- Degrees, Minutes, and Seconds: Angular measurement is used in addition to simple plane geometry to specify location on the earth's surface.
- This is based on a sexagesimal scale
- Great and Small Circles

Great and Small Circles

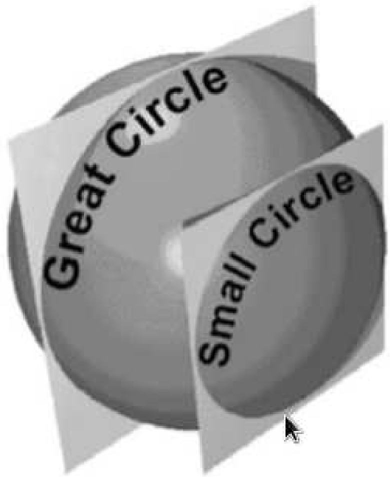

Figure 3.11: Great and small circles.

Projections

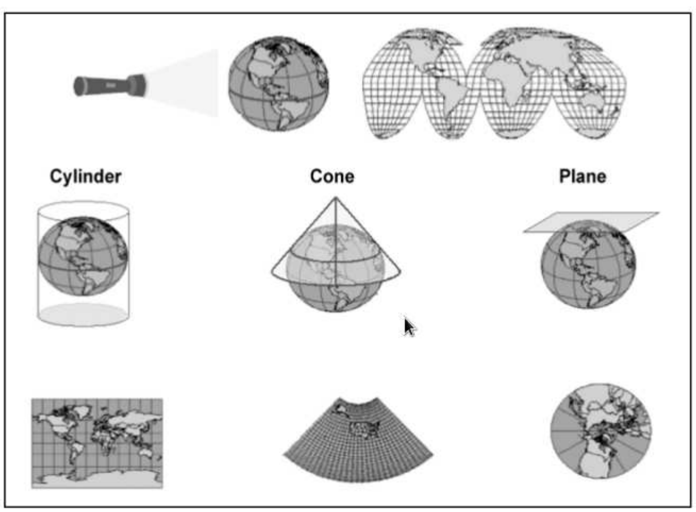

Figure 3.14: Map projections convert curved surface of the earth into a flat surface.