ENCYCLOPEDIA OF Geography

SAGE reference online

Altitude

Altitude is the distance between a position and a vertical reference surface. Distance might be measured in angular or length units. The position might be the point location of an object or a specified point along a vehicle track or satellite orbit. The surface might be one of many vertical datums, such as the center of the Earth, the surface of the ocean, the topographic surface of the Earth, the top of the built environment, or a constant barometric pressure surface.

The precise distance between a surface and a position depends on the definition of the line between them. For example, the line might be perpendicular to a plane tangent to the reference surface, or it might extend from the position toward the center of the mass of the Earth.

The terms *altitude, elevation*, and *height* are sometimes used interchangeably. In different contexts, these words take on different meanings, and the modifiers attached to them can sometimes clarify their usage. *Elevation* is often associated with the distance from a defined surface, such as the geoid, the theoretical equipotential gravity surface of the Earth, or a physically defined gravity surface model, such as a specific mean-sea-level datum, or with respect to the actual local-level plane as measured at the position. *Height* is sometimes reserved for the distance between a reference ellipsoid and a position or for the distance from the bottom to the top of an entity, such as a building or a mountain peak. The height of an aircraft might be the distance above the topographic surface of the Earth, while the height of a geodetic survey monument might be its vertical distance from a reference ellipsoid.

This sentence appears in a text on surveying principles: “Therefore, the altitude at which the plane must fly is calculated by adding the elevation of the mean datum to the flying height.” The *altitude* of the aircraft is above mean sea level, the flying *height* is the distance between the aircraft and the ground, and the ground (the mean datum) has an *elevation* with respect to mean sea level.

Altitude is modified by words that further specify the meaning. *Absolute altitude* refers to the distance above the physical surface of the sea or land. Angular *altitude* is the vertical angle between some plane (such as local level) and a line from the observation point to an object such as a mark on a surveyor's rod or a star. *Barometric altitude* is the distance from one constant pressure surface (an isobaric surface) to another. *Meridian altitude* is the vertical angle to an object measured along a line of longitude.

Peter H. Dana

Further Readings

American Society of Civil Engineers, American Congress on Surveying and Mapping, & American Society for Photogrammetry and Remote Sensing. (1994). *The glossary of mapping sciences.* Bethesda, MD: Author.

Kavanagh, B. F. , & Glenn Bird, S. J , (2000). *Surveying: Principles and applications.* Upper Saddle River, NJ: Prentice Hall.

National Geodetic Survey. (1986). *Geodetic glossary.* Rockville, MD: National Geodetic Information Center, Charting and Geodetic Services, National Ocean Service, National Oceanic and Atmospheric Administration.

Entry Citation:

Dana, Peter H. "Altitude." *Encyclopedia of Geography*. 2010. SAGE Publications. 26 Nov. 2010. <http://www.sage-ereference.com/geography/Article_n33.html>.

SAGE

ENCYCLOPEDIA OF
Geography

SAGE reference online

Coordinate Systems

Coordinate systems describe positions in space with one or more numbers. Coordinates can specify position as distance along a route, distance and direction from an origin, the intersection of two axes on a plane, the intersection of three axes in space, the intersection of spherical or ellipsoidal angles on the surface of the Earth, range circle or sphere intersections, a combination of vertical height and horizontal angles, or location with respect to celestial objects at a specified date and time.

Coordinate systems are sometimes called absolute methods of specifying location, as opposed to relative methods such as street addresses or proximity to landmarks. For the most part, coordinate systems can be converted, with some degree of uncertainty, from one coordinate system to another.

One of the most common coordinate systems used in geography is that of longitude, latitude, and altitude with respect to a specified horizontal and vertical datum. The spherical or ellipsoidal system of longitude and latitude angles is difficult to use for distance, direction, shape, or area estimation because longitude and latitude are not orthogonal to each other, are not equally scaled, and do not maintain a fixed relationship between their angular and distance dimensions on Earth. The Earth Centered, Earth Fixed X, *Y, Z* system (ECEF) defines a three-dimensional (3D) orthogonal coordinate system with the center of mass of Earth as the origin. ECEF makes vector distances and directions easy to compute in space but does not define any Earth surface and so cannot be used to compute distances and directions over an Earth surface.

To facilitate wayfinding, navigation, mapping, surveying, pointing to place, and the easy and accurate computation of distance, directions, and area, coordinate systems map portions of the Earth on a flat surface. Some coordinate systems implicitly describe point positions, while others describe areas on a surface or volumes in space. Coordinate systems are defined for local surveys, engineering drawings, regional surveying, country mapping, designation of international borders, continental and global mapping and modeling of climate change, plate tectonics, seismic activity, and exploration and mapping in space.

Surveyors and engineers often consider regions spanning less than 20 km (kilometers) to be reasonably approximated by a flat plane on which distances and directions are not appreciably influenced by the curvature of the Earth. Within 20 km, the distance difference between a line on a flat plane and the surface of an ellipsoid is less than 1 cm (centimeter). Local plane coordinate systems are defined by a point of beginning (POB), with arbitrary *X* and *Y* values, and a base line (BL) defining the rotation of the local system. Coordinates are given for other points in the system through *X* and *Y* coordinates or distances and directions with respect to the POB and BL. If the POB and BL in the local system are known with respect to another coordinate system, it is often possible to convert from a local plane coordinate system to other regional or global systems.

Small countries, provinces, states, departments, or groups of counties are often mapped and surveyed with respect to coordinate systems that are based on map projections and projection parameters. These systems allow approximate distance and direction estimates to be made with the *X* and *Y,* or easting and northing coordinates for points. More exact values of distance and direction can be computed using correction values based on the position of points and lines within the projection system. The State Plane Coordinate Systems of the United States, the British National Grid, the Costa Rican National Grids, and the Qatar National Grid are examples. The British and Qatar national grids are based on Transverse Mercator projections, the Costa Rican grids are Lambert Conformal Conics, and the U.S. State Plane System is based on almost an equal number of Lambert Conformal Conic and Transverse Mercator grids and a single Oblique Mercator projection used for southeastern Alaska.

Larger countries, provinces, or states are mapped with projections that allow position designation but are more difficult to use for precise surveys or engineering because they are more difficult to correct over longer distances. Most of the U.S. states have statewide systems for planning and transportation management that are based on a variety of projections, including Albers Equal Area, Lambert Conformal Conics, and Transverse Mercator systems.

When printed on maps, coordinate systems can identify feature positions on or above Earth. When used in geographic information system analysis, for finding a place or navigating with global positioning system receivers, coordinates must be associated with specific units, projections, projection parameters, and both horizontal and vertical geodetic datums to be unambiguous.

An example of a coordinate system in wide use is the Universal Transverse Mercator (UTM) system. UTM was defined in the 1940s by the U.S. Army as part of the Military Grid Reference System (MGRS). UTM maps the Earth from 80° S to 84° N with a series of six-degree longitudinal strips that divide the globe into 120 mapping planes, 60 above and 60 below the equator. These zones are numbered west to east with 60 easting zone numbers and designated south to north by 20 eight-degree latitudinal northing zones. With the exception of the Central Meridian, the line of longitude at the center of each easting zone, the projection parameters for each zone are the same. Above 84° N and below 80° S, MGRS uses the Universal Polar Stereographic (UPS) system.

Within MGRS, UTM designators are given as easting zone number, northing zone character, 100 km easting character, 100 km northing character, followed by easting digits and then northing digits. The number of digits indicates the precision with which the position is given. The UTM part of MGRS is now used as the U.S. National Grid, defined with reference to the North American Datum of 1983 (NAD83).

UTM is also now used all over the world, with more than 100 UTM versions based on dozens of different geodetic datums. The UTM coordinates of a single point, often given as easting zone and northing zone, followed by the easting digits and northing digits, can differ by hundreds of meters when referenced to the wrong reference ellipsoid or geodetic datum. The same can be true for any coordinate system. Careful definition of coordinate system parameters is required for unambiguous use in positioning and analysis.

Peter H. Dana

Further Readings

Iliffe, J. , & Lott, R. (2008). *Datums and map projections: For remote sensing, GIS, and surveying (2nd ed.).* New York: Taylor & Francis.

Maling, D. (1992). *Coordinate systems and map projections (2nd ed.).* New York: Pergamon Press.

Entry Citation:

Dana, Peter H. "Coordinate Systems." *Encyclopedia of Geography*. 2010. SAGE Publications. 26 Nov. 2010. <http://www.sage-ereference.com/geography/Article_n217.html>.

Datums

A geodetic datum is a fixed reference point according to which the size and shape of Earth are measured. They are also used in measuring gravitational pull and rotation. There are at least three kinds of geodetic datums used in geography. Vertical datums form the zero surface for vertical measurements of altitude and elevation. Horizontal datums define the size and shape of Earth and the origin and orientation of a horizontal coordinate system. Complete datums can provide both vertical and horizontal zero origins and coordinate system definitions. Some complete geodetic datums define Earth's shape, horizontal and vertical coordinate system origins, gravity fields, and physical constants such as rotational velocity and Earth's gravitational constant.

Without a vertical datum, the altitude of a point is ambiguous, and without a horizontal datum the longitude and latitude of a point are not sufficiently well-known to locate it on the Earth. With the specification of a vertical zero, such as the ground level, the mean sea level, or the surface of a particular reference ellipsoid, the elevation of a point can be known. If the equator is defined as the origin for lines of latitude, and Greenwich, England, is defined as the origin for lines of longitude, then any point can be found to at least within a few kilometers on the globe. To specify a position to within a few meters, coordinates must be associated with specific geodetic horizontal and vertical datums.

Since the French geodetic expeditions of the mid 1700s to Peru and Lapland, Earth has been considered to be a slightly flattened sphere, a spheroid, an ellipse of rotation, or an ellipsoid. There have been dozens of different Earth shapes on which mapping systems and coordinate systems have been based. While there have been other Earth shapes proposed and used in geodesy, most are specified as ellipsoids with an equatorial radius and either a polar radius or a parameter that represents the relationship between the equatorial radius and the polar radius.

The equator forms the zero point for lines of latitude. There is no equivalent physical feature on Earth that naturally lends itself to the origin for lines of longitude. The zero point, or zero line of longitude, the *prime meridian,* has been defined at different times by different interests to pass through 1 of more than 20 cities, including Moscow, Paris, Madrid, Rio de Janeiro, Lisbon, the Canary Islands, Washington, Tokyo, and Greenwich, England. A geodetic datum defines at least a single monument with a specific longitude and latitude as well as the distance and direction to another monument.

Most modern datums use a network of monuments to define a system of longitude and latitude or vertical heights over regions covering small islands, countries, continents, or the entire Earth. The Cape Canaveral Datum is a local datum defined for use in Florida and the Bahamas. The North American Datum of 1983 (NAD83) is a regional horizontal datum. The U.S. National Geodetic Vertical Datum (NAVD 88) is a regional vertical datum. Geodetic Reference System 1980 (GRG80) is a global horizontal geodetic datum. World Geodetic System 1984 (WGS-84) is a complete global geodetic datum with both horizontal and vertical components, as well as Earth's gravitational and rotation parameters.

Peter H. Dana

Further Readings

Burkard, R. (1983). *Geodesy for the layman.* Washington, DC: National Oceanic and Atmospheric Administration.

National Imagery and Mapping Agency. (1997). *Department of Defense world geodetic system 1984: Its definition and relationships with local geodetic systems (3rd ed.* , NIMA TR8350.2). Bethesda, MD: National Imagery and Mapping Agency.

Torge, W. (1991). *Geodesy (2nd ed.).* New York: de Gruyter.

Entry Citation:

Dana, Peter H. "Datums." *Encyclopedia of Geography*. 2010. SAGE Publications. 26 Nov. 2010. <http://www.sage-ereference.com/geography/Article_n261.html>.

ENCYCLOPEDIA OF
Geography

SAGE reference online

Earth's Coordinate Grid

Gridding the globe with abstract lines has been put forward since the 2nd century BC, when Hipparchus suggested parallels of latitude and meridians of longitude constructed over a spherical model of Earth. Three hundred years later, Claudius Ptolemy refined these ideas and produced map projections with a graticule of longitude and latitude lines.

After the French-sponsored geodetic expeditions in Peru and Lapland in the 1730s, the ellipsoidal shape of the Earth became the basis for more accurate positioning of lines of latitude. After the International Meridian Conference of 1884 recognized the center of the transit instrument of the Royal Observatory at Greenwich, England, as the zero origin for longitude, the prime meridian, most nautical charts, and many maps agreed on the alignment of the longitude and latitude on small-scale charts and maps.

Spherical trigonometry is sufficient for distance and direction computations on the sphere, but the ellipsoidal shape of Earth makes these computations difficult. Additionally, the very meaning of distance is changed by different conceptions of appropriate paths from one point to another. Gerardus Mercator designed a map projection in 1569 that allowed one to plot a single compass bearing as a straight line on a map. The course followed by steering this single azimuth is not the shortest path from one point to another, but often the efficiency of steering a single bearing and the ease of course design makes the longer path worthwhile. On a spherical Earth surface, the shortest path is a great circle. On the sphere, the meridians of longitude all describe great circles. The parallels of latitude describe small circles, not the shortest path between points of the same latitude, unless they are both on the equator. The shortest path over the surface of an ellipsoidal Earth is the ellipsoidal geodesic. Following any great circle or geodesic other than along a meridian or the equator requires continuously changing the heading with respect to true north. On the ellipsoidal Earth, spherical trigonometry is not sufficient for computations of distance, direction, area, path intersection, and other practical problems. Software to perform geodetic direction and distance algorithms can require several pages of source code. Software for projecting the ellipsoidal Earth onto a flat plane can be complex and slow to execute for large geodatabases.

There are other global coordinate systems based on longitude and latitude. In the *plate carrée* projection, the lines of longitude and latitude are mapped as though they were orthogonal and equally scaled everywhere. The World Geographic Reference System and Maidenhead Grid Squares divide the surface of Earth into nested rectangles in longitude, latitude space described by alphanumeric characters. These are useful for pointing to positions or small regions, but dividing the world up into equal areas using longitude and latitude is as impossible as flattening Earth with a single map projection without introducing distortions.

While longitude and latitude are useful, especially for storing of database vertices, for index maps, and for point descriptions, there are major problems for mapping, navigation, and spatial analysis. Hundreds of useful map projections have been devised, resulting in local and regional coordinate systems with which distances, directions, areas, and shapes can be portrayed and measured. These map projections, based on the notion of flattening all or a portion of Earth's surface onto a flat plane, all fail to portray the Earth without distortion. Cylindrical, conic, and flat planes are geometric surfaces on which features on Earth's surface are projected. Cartographers can minimize one or more distortions of distance, directions, area, local shape, or global shape but never all of them. Small local regions can be portrayed on large-scale maps with reasonable fidelity, but tiling such maps to cover larger areas is not possible without overlaps or gaps. Global portrayals of Earth at smaller scales are often based on compromise projections that introduce minimal distortion of a few characteristics.

While Greenwich and the equator are meaningful concepts as the origin for longitude and latitude, they are not sufficient for mapping and positioning, especially at large scales. Geodetic datums are models of the size and shape of Earth and for the origin and orientation for longitude and latitude. The problem is that there have been many Earth shapes and many prime meridians, even those that pass through Greenwich. Distance and direction computations can differ significantly when different Earth radii are used. Maps and databases referenced to one geodetic datum can have point positions that differ by hundreds of meters when inappropriately tied to the wrong datum.

Geographic databases are often associated with a specific scale or resolution. They are appropriate for display and analysis within a limited range of scale. We live now in a time when large-scale mapping and spatial analysis is often done over long distances and wide areas. Research efforts are underway to develop multiscale data sets that can be used appropriately over a broad range of mapping and analysis scales. Scale-appropriate smoothing and thinning of large-scale databases could result in global databases based in longitude and latitude that could be projected on the fly for display and analysis. There are attempts to tile the globe and the ellipsoid with equal-area regions based on hierarchical global tessellations in triangular or hexagonal shapes. Global elevation data sets can be similarly processed for use at multiple scales.

Peter H. Dana

Further Readings

Brown, L. A. (1977). *The story of maps.* New York: Dover.

Dutton, G. H. (1999). *A hierarchical coordinate system for geoprocessing and cartography.* New York: Springer.

Robinson, A. H. , Morrison, J. L. , Muehrcke, P. C. , Kimerling, A. J. , & Guptill, S. C. (1995). *Elements of cartography (6th ed.).* New York: Wiley.

Snyder, J. P. (1987). *Map projections: A working manual (USGS Professional Paper No. 1395).* Washington, DC: Government Printing Office.

Entry Citation:

Dana, Peter H. "Earth's Coordinate Grid." *Encyclopedia of Geography*. 2010. SAGE Publications. 26 Nov. 2010. <http://www.sage-ereference.com/geography/Article_n310.html>.

ENCYCLOPEDIA OF Geography

SAGE reference online

Equator

The equator is the great circle farthest from the north-south spin axis of Earth. The equator is everywhere equidistant from the North and South poles on the surface of Earth, which is a sphere or a reference ellipsoid.

Although the equator is easy to define, it is not easily found and marked on Earth. The gravitational force is lower along the equator since it is the circle on the ellipsoid farthest from the center of mass of Earth. The equator marks the line above which the Coriolis force deflects movement toward the left of the direction of travel and below which the deflection is to the right. While these effects are real and influence weather patterns, ocean currents, and aircraft flight, they are so weak as to be almost immeasurable at the equator. Polaris, the polestar, can be used to find zero latitude, but atmospheric effects make it difficult to observe accurately at the equator.

However the equator is defined by any of more than 100 geodetic datums in use in the world, it is a physically definable origin for latitude. The *geodetic equator* is the circle on the surface of a reference ellipsoid equidistant from the poles of rotation of the ellipsoid. For different ellipsoids, the geodetic equator can be in different places on the physical surface of Earth.

Since there are various definitions for other latitudes, there are other equators found along the line representing 0° of those latitudes. There is a *celestial equator,* defined with respect to celestial latitude, an *astronomic equator,* a *galactic equator,* a *geomagnetic equator,* and others.

The equator has meanings in many contexts. The geostationary weather and communications satellites orbit Earth above the equator. The tropical sun's rays are at their highest at midday along the line. Along its course, tropical rain forests, massive river systems, and sparse populations are found on land. At sea, sailing ships can be trapped in the equatorial doldrums, and sailors still perform ceremonies for those crossing the line for the first time. Joseph Conrad, Mark Twain, and Herman Melville have used the equator in the titles of their books. There have been over a dozen films with “equator” in the title. There is a region known as Equateur in the Republic of Congo, the Equatorial Channel in the Indian Ocean, the countries of Equatorial Guinea and Ecuador, and the group of Pacific islands known as the Line Islands or the Equatorial Islands.

There are dozens of equatorial monuments in South America, Africa, and Asia, but they are often tourist facilities more than they are accurate markers of the location of the zero for the variously defined systems of latitude. For example, the Mitad del Mundo monument in Ecuador marks the approximate position of zero latitude for a system no longer in use in Ecuador or anywhere else in the world. On Ecuadorian topographic maps, the monument is responsibly placed several hundred meters above the line representing zero latitude for the Provisional South American Datum of 1956. GPS-equipped visitors to the Middle of the World will find the World Geodetic System of 1984 zero latitude a few hundred meters north of the monument.

Peter H. Dana

Further Readings

Clark, T. (1997). *Equator: A journey.* New York: Avon.

Cosgrove, D. (2008). *Seeing the equator.* In *Geography and vision: Seeing, imagining and representing the world* (pp. pp. 203–218). London: I. B. Tauris.

Entry Citation:

Dana, Peter H. "Equator." *Encyclopedia of Geography*. 2010. SAGE Publications. 26 Nov. 2010. <http://www.sage-ereference.com/geography/Article_n388.html>.

ENCYCLOPEDIA OF
Geography

SAGE reference online

Global Positioning Systems

The *global positioning system* (GPS) is a satellite-based navigation system designed and operated by the U.S. Department of Defense (DoD). GPS can provide three-dimensional (3D) position and guidance in any weather and at any time of the day over the entire surface of the Earth, in the air, and in low space orbits. GPS consists of a control segment run by DoD, a space segment consisting of 24 or more satellites, and a user segment that includes military and civilian receivers.

GPS evolved from earlier regional and global radio navigation systems such as the Navy Transit System, Omega, and Loran-C. It was first described in the mid 1970s, and by 1985, there were enough satellites to allow development and testing of receivers for land, sea, and air navigation and guidance as well as for time and frequency dissemination and for both geodetic and plane surveying. The system was declared fully operational in 1995.

There is a wide range of GPS services and techniques with different capabilities, limitations, and costs. There are two primary services that are provided by GPS and controlled by DoD. The Precise Positioning Service (PPS) is for use by the U.S. military, approved allied armed forces, and some agencies of the U.S. government. The PPS provides for encryption of the PPS bit stream (the P-Code) that is transmitted by the GPS satellites, mitigating the threat of spoofing, or tricking, a military receiver into tracking GPS-like signals transmitted by an adversary. Decrypting the PPS signals requires authorization and access to secure cryptographic keys.

The Standard Positioning Service (SPS) is now available, without restriction or charge, to everyone. For a time, between 1990 and 2000, the SPS bit stream (the C/A code) was intentionally degraded by Selective Availability to deny high-accuracy positioning to non-DoD users. The SPS, sometimes known as civilian GPS, is used throughout the world by a wide range of users in a wide variety of applications. Recreational hikers and boaters, users of automobile navigation systems, general aviation pilots, and data attribute collectors use inexpensive receivers to track the SPS signals.

The 24 or more GPS satellites orbit the Earth every 12 hrs. (hours). Earth rotates beneath the constellation, so the ground track of the satellites repeats in just less than 24 hrs. Monitored, adjusted, and provided with orbital and clock information by the control system, the satellites send their positions, their atomic clock errors, and complete system information on a bit stream called the Navigation Message. Relative ranges to satellites are determined within the receiver by lining up bit streams (P-Code and C/A code) sent by the satellites with identical codes produced in the receiver. The Navigation Message is sent from the satellites to the receiver over microwave frequency carrier signals that “spread” the SPS and PPS codes to resemble noise. When the receiver aligns its version of the codes with the noiselike GPS signals, the carrier frequencies are “de-spread,” providing the receiver with the contents of the Navigation Message and a code-phase relative arrival time for each satellite signal. Using at least four satellite messages and code-phase arrival times, a GPS receiver can produce a full 3D position solution and a correction for the receiver's inexpensive clock.

SPS GPS can provide GPS receivers operating under optimal conditions with horizontal positioning errors of 3 m (meters) and vertical accuracies of 5 m. These levels of accuracy are 95% figures and require an antenna with a full and unobstructed view of the sky so that sufficient numbers of satellites and good enough geometry (satellites must be evenly spread out in the sky for robust positioning) can be obtained. Local reflections from building and ground surfaces can interfere with GPS tracking. Trees, some foliage, metal, many building materials, and even the human body can block GPS signals from getting to the GPS antenna with sufficient signal strength to allow for position determination. While there are some assisted and low signal-strength approaches to GPS receiver design, GPS remains an outdoor system requiring care on the part of the user to obtain useful position information.

Some GPS bias errors, including signal delays introduced by the ionosphere and troposphere, orbital parameter errors, and GPS satellite clock errors, can be reduced by applying corrections for each tracked satellite signal. Differential GPS (DGPS) uses corrections produced by one or more reference GPS receivers to improve the position accuracy of a remote receiver at an unknown position. The precisely located DGPS reference receiver produces corrections in the form of time-tagged range error and rate-of-range error parameters for each satellite along with codes identifying which orbital and clock parameters the corrections relate to. DGPS is not based on position corrections. The remote receiver position is computed after applying the range corrections for each satellite used in the remote receiver position solution.

DGPS is the basis for a wide variety of GPS approaches. Real-time, code-phase DGPS can make use of range corrections transmitted from ground-based or communications satellite radio transmitters. These real-time DGPS systems can provide 1-m accuracies when the receiver is within a few hundred kilometers of a DGPS reference station. Other systems such as the U.S. Federal Aviation Administration Wide Area Augmentation System provide corrections based on models for signal biases computed from a network of monitor receivers. These network solutions can result in 3-m accuracies anywhere within the national airspace service area of the system.

DGPS postprocessing can be accomplished if both remote and reference receivers store sufficient information to couple corrections with measured arrival times and orbital and clock data sets. Many commercial and public agencies provide Internet access to DGPS data for postprocessing. Geodesists use receivers separated by thousands of kilometers to measure tectonic movement by measuring over many hours. Surveyors make use of de-spread GPS carrier signals, low-noise receivers, special software techniques, and continuous tracking to produce relative position estimates over baselines of 10 to 30 kilometers.

Peter H. Dana

Further Readings

El-Rabbany, A. (2006). *Introduction to GPS: The global positioning system.* Norwood, MA: Artech House.

Hofmann-Wellenhof, B. , Lichtenegger, H. , & Collins, J. (2004). *Global positioning system: Theory and practice.* Berlin, Germany: Springer.

Parkinson, B. W. , ed. , & Spilker, J. J. (Eds.). (1996). *Global positioning system: Theory and practice* (Vols. 1 & 2). Washington, DC: American Institute of Aeronautics and Astronautics.

Entry Citation:

Dana, Peter H. "Global Positioning Systems." *Encyclopedia of Geography*. 2010. SAGE Publications. 26 Nov. 2010. <http://www.sage-ereference.com/geography/Article_n525.html>.

ENCYCLOPEDIA OF
Geography

SAGE reference online

Latitude

Latitude is the angular distance of a position from the equator to the nearest pole. However, latitude can acquire different meanings if inappropriately applied to other locations on Earth.

Often expressed in degrees from the equator (positive north and negative south), latitude can be expressed in a variety of units (radians, grads, semicircles, arc seconds, or mils) and formats (+/-or N/S, to indicate the hemisphere; degrees: minutes and fractional minutes; or degrees: minutes: seconds and fractional seconds). Since one minute of latitude is equal to one nautical mile latitude, tick marks are used on charts as a local graphic scale. Without reference to a specific geodetic datum, latitude values will point to different places on Earth.

If Earth were perfectly spherical, then the general definition for *geographic latitude* might suffice—that is, the angle from the equatorial plane for a line from the center of mass of the spherical Earth to a position. Earth and its gravity field are slightly elliptical in shape. The distance from the center of Earth to the equator is about 21 km (kilometers) longer than the distance from the center to either pole. A consequence of this flattened spherical shape, an ellipsoid of rotation, is that the force of gravity is only exactly toward the center of mass of Earth along the equator or at either pole. Everywhere else, the plumb bob, the bubble level, or the horizon at sea, the references for local level, are affected by the ellipsoidal gravity surface that is perpendicular to a line from a position toward but slightly away from the center of the Earth. The angle between the equatorial plane and a line perpendicular to the ellipsoid surface that passes through a position is the *geodetic latitude*.

There are other latitudes. If one measures position with respect to a sphere that has the same surface area as a reference ellipsoid, the north-south angle is the *authalic latitude*. *Geocentric latitude* is the angle, similar to *geographic latitude* for a sphere, between the equatorial plane and the center of the ellipsoid. There is a *parametric* (or *reduced*) *latitude*, defined as the angle between the equatorial plane and a line from the center of the ellipsoid perpendicular to a surface defined by a sphere tangent to the ellipsoid along the equator or the latitude on a sphere for which the parallel has the same radius as the parallel of geodetic latitude on the ellipsoid through the same point. *Conformal latitude* is a transformation of *geodetic latitude* that allows a conformal mapping using spherical geometry. *Isometric latitude* is proportional to the parallels on an ellipsoidal Mercator projection. *Rectifying latitude* is the angular distance along a line of longitude from the equator to a point on Earth.

Other latitudes have been defined on Earth, including *astronomic*, *auxiliary equidistant*, *geomagnetic*, *magnetic*, and *transverse*. Surveyors use the word for the *y* value in a traverse defined in a plane coordinate system.

The importance for geography is that these latitudes are represented by significantly different angles, making their appropriate selection and use critical for positioning and analysis.

Peter H. Dana

Further Readings

American Society of Civil Engineers. (1994). *The glossary of mapping sciences.* Bethesda, MD: Author.

National Geodetic Information Center. (1986). *Geodetic glossary.* Rockville, MD: Author.

Snyder, J. P. (1987). *Map projections: A working manual* (USGS Professional Paper No. 1395). Washington, DC: Government Printing Office.

Torge, W. (1991). *Geodesy (2nd ed.).* New York: deGruyter.

Entry Citation:

Dana, Peter H. "Latitude." *Encyclopedia of Geography*. 2010. SAGE Publications. 26 Nov. 2010. <http://www.sage-ereference.com/geography/Article_n705.html>.

ENCYCLOPEDIA OF Geography

SAGE reference online

Longitude

Longitude is the angular distance around Earth from a reference plane that defines a prime meridian. A meridian is synonymous with a line of longitude. Some conventions apply to angular expressions of longitude. One is that the angle is expressed counterclockwise with respect to the view from the North Pole to the South Pole. Sometimes, the angle from the zero meridian is stated as a value from 0° to 360°. The other convention is to express the longitude as a negative value from 0° to -180° west from the prime and as a positive value from 0° to +180° east of the prime. Longitude can be expressed in a variety of units (radians, grads, semicircles, arc seconds, or mils) and formats (+/- or E/W, to indicate the hemisphere; degrees: minutes and fractional minutes; or degrees: minutes: seconds and fractional seconds).

The determination of longitude on the surface of Earth is difficult because there is no physical meaning to any prime meridian. The prime meridian has been variously located in Amsterdam, Athens, Beijing, Djakarta, Berlin, Bern, Brussels, Copenhagen, the Canary Islands, Helsinki, Istanbul, Lisbon, Madrid, Moscow, Oslo, Paris, Rio de Janeiro, Rome, St. Petersburg, Stockholm, Tokyo, Washington, and other places. It was not until the 1884 Meridian Conference that Greenwich, England, was selected as a suitable common prime meridian for the 22 attending countries, a decision based on the dominance of British charts in navigation. The Greenwich prime was defined as the center of the Royal Observatory transit telescope. Since then, most geodetic datums in use place the actual zero line of longitude a few tens of meters east or west of the original transit instrument. Even a datum used within Britain, such as the Ordnance Survey of 1936, places the zero line of longitude several meters away from the original Greenwich meridian. Without reference to a specific geodetic datum, longitude values will point to different places on Earth.

Since the establishment of an implied zero meridian in the 1960s by the *Bureau International de L'Heure*, modern geodetic datums fix the zero line of longitude not with a single point or line but based on a network of observatories around the world with longitudes whose offset from zero is defined. Geodesists may base their zero line of longitude on the International Earth Rotation Service's International Terrestrial Reference Frame (ITRF), which is updated to a new version every few years to account for continental drift. Modern global geodetic datums, such as the World Geodetic System of 1984 (WGS-84), are occasionally reset to ITRF, slightly changing the location of the zero line of longitude.

Peter H. Dana

Further Readings

Cross, P. A. *Position: Just what does it mean? Journal of Navigation* vol. 43 no. (2) pp. 246–262. (1990).

Howse, D. (1980). *Greenwich time and the discovery of the longitude.* Oxford, UK: Oxford University Press.

Sobel, D. (1998). *Longitude.* London: Fourth Estate.

Entry Citation:

Dana, Peter H. "Longitude." *Encyclopedia of Geography*. 2010. SAGE Publications. 26 Nov. 2010. <http://www.sage-ereference.com/geography/Article_n726.html>.

SAGE

ENCYCLOPEDIA OF Geography

SAGE reference online

Participatory Mapping

Participatory mapping (PM) is an umbrella term for a broad spectrum of mapping activities. Based to some extent on participatory action research and countermapping, participatory mapping describes mapping projects within which agendas, approaches, processes, techniques, and control rest in some part with the people whose territories and places are being mapped. PM projects have included the mapping of environmental hazards in neighborhoods, the “green mapping” of environmental resources and natural spaces in cities, the mapping of indigenous territorial claims, mapping for resource management, and public participation in zoning and development code mapping.

Other names for PM activities include community mapping, participatory geographic information systems (PGIS), public participation GIS (PPGIS), and participatory rural appraisal (PRA). PM based on three-dimensional (3D) terrain models is called P3DM. Mapping to balance or end control of territory by outsiders is known as countermapping or remapping.

PM projects have taken place worldwide. They have been based on a variety of mapping methods, including sketch maps, 3D models, maps traced from topographic maps, maps drawn on existing base maps, maps based on aerial photographs or satellite imagery, GIS products, global positioning system (GPS) measurements, and Google Earth displays.

Approaches to PM have ranged from grassroots projects instigated, carried out, and controlled by local groups to top-down, externally funded and controlled projects that have granted only token participation to people from the affected communities. Participation has come to suggest such a wide range of activities and levels of control that PM has recently been viewed with suspicion.

Different levels of local participation range from top-down externally controlled to bottom-up community designed and completed projects. Simply calling a project “participatory,” however, is not a sufficient way to justify a project and does not ensure an appropriate level of participation.

The following are examples of the range of local stakeholder participation:

Top-down design and control

Only token local participation

All decisions made by outsiders

Maps made by outside experts

Tasks assigned to community members

Local people working together with outsiders

Outsiders and local people sharing knowledge

Local people setting the agenda

Local people producing project maps

No outsiders taking part

Bottom-up design and control

Important questions that should be asked prior to undertaking a PM project include the following: What is the purpose of the project? Who will pay for the project? What region is to be mapped? Who decides what happens? Who are the stakeholders? Who will be excluded from the process? Who sets the priorities for the project? Who are the “key” informants? Who will learn the mapping skills? How will conflicts be resolved? Who will control the results? How will the maps be disseminated? Who will maintain the maps? Who will be responsible for the future of the project?

The work flow for a typical PM project includes the following steps:

Recognition of need

Community request for assistance

Organizational meetings

Regional meetings

Community meetings

Training workshops Pilot projects

Mapping workshops

Ethnographic investigations

Boundary measurements

Land use measurements

GIS processing

Map production

Ethnography publication

Technology transfer

Negotiation for land rights

Land claims may not be successful just because a community makes a map. Maps may have to compete in bureaucratic and judicial arenas with the maps produced by the state or by resource management agencies. Sketches, artistic depictions of place, and 3D models may be useful at various stages of a project, but PM products may have to incorporate coordinate system grids, standardized symbols, and other cartographic conventions to compete with existing maps. GIS offers PM projects the chance to produce high-quality maps that can carry significant weight in court. Some successful indigenous-community PM projects have combined accurate and technically sophisticated maps with ethnographies, drawings, and photographs, presenting a strong case for their land tenure claims.

It should be noted that participatory mapping projects have been criticized as being reductionist and too technical, elitist, and damaging to local conceptions of territory and community. The proposed PM projects can unrealistically raise community expectations. In contested places, the mapping process can expose participants to danger. Without a plan for the future, a PM project can leave a community exposed to threats from the state or from outsiders. Maps construct territory, and so the maps from a PM process can be used and misused. Putting lines on maps where none existed is both powerful and dangerous. Lands shared by communities can be redefined as contested spaces through a PM process.

The methods selected for a PM project can change ideas of territory. Using GPS to put boundary turning points on maps can exclude distant hunting grounds or seasonal settlements. Surveyors traversing a boundary can assume that traditions of property are the same everywhere. Using existing base maps can give imbalanced weight to features included on standard topographic maps. Map legends that use official languages may have little meaning to participants.

On the other hand, PM projects can empower communities and protect local resources. Local participation can add crucial ground truth that is difficult to obtain in any other way. GPS can be an effective tool for mapping places that may never have been mapped. GIS can aid in the mapping and analysis of subsistence strategies, sacred spaces, community extents, and shared lands. A PM project that is well designed and thoughtfully carried out can combine activism, local knowledge, and community conceptions of place to define, depict, justify, and control territory in a way that can effectively claim space and counter the power of outsiders.

Peter H. Dana

Further Readings

Chapin, M. , Lamb, Z. , and Threlkeld, B. *Mapping indigenous lands. Annual Review of Anthropology* vol. 34 pp. 619–638. (2005).

Dana, P. H. (2008). *Surveys of people and place.* In J. P. Wilson, ed. & S. Fotheringham (Eds.), *Handbook of geographic information science* (chap. 28, pp. pp. 494–518). Oxford, UK: Blackwell.

Flavelle, A. (2002). *Mapping our land: A guide to making maps of our own communities and traditional lands.* Edmonton, Alberta, Canada: Lone Pine Foundation.

Society for Applied Anthropology. Human organization: Participatory mapping of indigenous lands in Latin America [Special issue]. Human Organization vol. 62 no. (4). (2003).

Entry Citation:

Dana, Peter H. "Participatory Mapping." *Encyclopedia of Geography*. 2010. SAGE Publications. 26 Nov. 2010. <http://www.sage-ereference.com/geography/Article_n863.html>.