THE DEFINITION OF LOCATION

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1. Nominal, ordinal and quantitative scales of measurement

It may be assumed that when man first began not only to relate to particular geographical objects in his environment but to convey their location to others of his species, he used verbal descriptions of the properties of the object in question, as well as physically pointing out their direction in relation to the speaker. An indication of distance must have come at a later stage. As was pointed out already in the introductory paper to this course (see *Introduction to Toponymy*), giving names to objects, whether living or inanimate, must have been one of the earliest intellectual activities of the human race. However, before an object can be named it must be identified. In the case of living things, which are mobile rather than fixed to a particular location, this usually involves relating to the properties of the subject. Identifying immovable objects, and especially different objects belonging to a single category of items, must involve a definition of location – otherwise there would be no possibility of distinguishing between them. This is particularly true of topographic features which make up categories or feature classes: mountains, rivers, lakes, islands and many others. In this lecture we shall briefly investigate how the location of geographical features – which are the objects of toponymy can be defined.

All measuring activities, in the widest sense, can be conducted on three main scales". The first is the nominal scale: here, each item is distinguished from all others in the set by its nature, and therefore it can be named (hence the term *nominal*, from Latin *nomen*, *name*) — but not graded. Examples are soil types, human occupations or professions (disregarding income or social status!) or newspapers. The second is the ordinal scale (from Latin *ordo*, order), in which items of a set can be arranged or graded in a clearly-defined procession or order, e.g. by size, intensity, value etc. — but not measured quantitatively. Military ranks, university degrees or the contestants in a beauty contest are examples of items arranged on an ordinal scale, as are roads graded by arteriality or rivers by their stream order.

Finally there is the quantitative scale, on which objects can be measured in a metric" way, i.e. with a measuring tape, thermometer, scales, monetary system or other measuring device: income, intelligence quotient (I.Q.), distance, angle, etc. Strictly speaking, quantitative scales can be divided into two types. Interval scales have fixed units but no intrinsically fixed origin; angles, which can be measured from any direction, are an example, as is temperature, which, in the Centigrade, Fahrenheit and Kelvin scales has different zero points. On the other hand ratio scales are those which have a "naturally" fixed zero or point of origin, three examples being length, weight and azimuth (angle of direction, always measured clockwise from North).

In this text we shall refer to both interval scales and ratio scales under the single heading of quantitative scales.

2. Defining locations on different scales

A place on Earth – or, for that matter, on a celestial body such as the moon or a planet – can be defined in a number of ways. Coordinates such as geographical latitude and longitude, or plane topographic coordinates such as the UTM grid, constitute a quantitative definition, as will be shown in more detail in the next paragraph. A named or numbered grid square such as B-5 in a town plan forms an ordinal definition, because only an orderly progression of map squares is provided as reference frame for the geographical objects, not precise measurements. Last – but earliest in historical development – is the verbal description of location, i.e. by a name. Each method has its advantages and disadvantages. As we shall demonstrate, coordinates are precise to a point (and define an error square, the size of which depends on the smallest unit used in the coordinates); an ordinal grid rectangle is more comprehensive and is better understood by many readers, but includes on the average many dozens or even hundreds of names.

What, then, are the advantages of designating a geographical feature by its name? Primarily, a name is more easily remembered by most person than a set of numbers. Secondly, in many cases some mental connotation can be attributed to the name. Thirdly, a single name can indicate not only a small object such as a spring or a cave, but also a larger area such as a city or even an entire continent or an ocean. Fourthly and chiefly, a name can often supply an appreciable amount of information about the location referred to, such as the type of place it is, and in

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**) International Institute for Geoinformation and Earth Observation, Enschede, The Netherlands many cases about its cultural, political and historical background.

Are there any drawbacks to designating a place only with the aid of its name, besides the lack of precision for a point object? Yes, there are three. Firstly, one name often refers to several geographical features. Let us take the name Bethlehem. In Israel alone there are two Bethlehems: one in Judea, South of Jerusalem, also called Bethlehem-Judah in the Bible (Judges 19,2), and one in Galilee (Joshua 19,15). But in South Africa there is also a Bethlehem, namely in the Orange Free State, and we find cities and towns named Bethlehem (or its derivatives, i.e. its conversions and exonyms) in at least 1 5 other countries. So the place name itself does not supply a complete definition of the location, and we may have to add the name of the country and perhaps even the district. Secondly, a specific geographical feature may have more than one name. A Dutchman may refer to his country's capital as Den Haag; a foreigner will look up the place in his atlas and find the Hague or 's-Gravenhage, and will be unaware that he has, indeed hit upon the correct place. Thirdly, in this age of computers and information technology a quantitative definition of location is indispensable for geographical processing, especially in maps.

Incidentally, the first disadvantage mentioned above in connection with names as locators applies also to the ordinal definition of location by map squares: a single square may include more than one appearance of a specific toponym. This is certainly true of names such as Nooitgedacht, which appears dozens and perhaps hundreds of times in South Africa.

3. The geographical graticule and the topographic grid

From the above it becomes clear that for a precise and unambiguous definition of location a quantitative method is mandatory. This is supplied by the various "coordinate systems" with which we shall deal in this paragraph. No proper gazetteer of geographical names is complete without reference to the quantitative coordinates of each name.

Geographical coordinates seem to be the most ancient quantitative method of defining location, at least in western culture. The earliest list of geographical names complete with quantitative locators is Ptolemy's *Geographia* of the 2nd cent. AD, which records some 8000 places by their names and their geographical coordinates. The net of lines of latitude on the globe, also called parallels (because their planes are parallel to that of the equator), and of lines of longitude or meridians (which are half "great circles" extending from pole to pole), is called the geographical *graticule*. Latitude of a place on the globe (and one should never forget that all toponyms refer to places on a *spherical* body) is measured north or south from the equator as angles, in degrees, minutes and seconds. Longitude is similarly measured as an angle east or west from the prime meridian of Greenwich, England.

These measurements thus constitute a precise quantitative system, and its degree of precision is limited only by the number of figures after the decimal point.

In spite of what has been said above concerning the sphericity of the Earth. it is sometimes convenient to deal with only a limited portion of the Earth's surface and regard this not as curved but as a plane.

This is what every conventional topographic map enables one to do, and the method of transferring places from the spherical surface of the Earth to the plane map sheet is called a cartographic projection. Since the representations of the lines of the graticule in a plane map are curved (except in the so-called cylindrical normal projections), and therefore inconvenient for measuring coordinate values from them, it is common practice to superimpose a plane rectangular net of squares on the map, of the well-known type called cartesian coordinates or **plane rectangular coordinates**, and this is called a topographic or local grid, or, if it covers a national territory, a national grid, the coordinates then being called national coordinates. Such a grid is always based on a particular cartographic projection and it has a point of origin from which the coordinate values are measured.

4. Plane rectangular coordinate systems

As mentioned, geographical (j, l) or rectangular coordinates (x, y) can be used to locate geographic features. Each feature with geographical coordinates on the reference surface of the Earth may be transformed to rectangular coordinates (x,y) representing positions on the map plane (see figure 1).

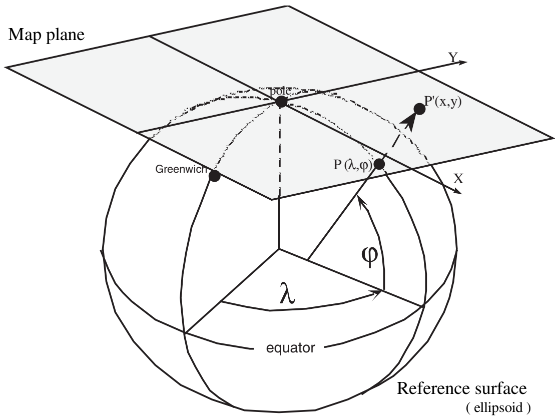

Figure 1 – Plane rectangular coordinate systems

In other words, each feature may be transferred from the curved surface of the earth, approximated by a reference surface, to the flat plane of the map by means of a map projection.

5. Projection systems

The table below gives an overview of some commonly used projection systems, with an annotation that discusses their properties, as relevant for specific uses of these maps. The projections are categorized according to projection plane..

Projection	Remarks
Cylindrical	
Central cylindrical	Map is perspective but not conformal nor equal area. Projected perspectively from the center of the earth onto a cylinder tangent to the equator. Only used for teaching purposes.
Equidistant cylindrical	Also called Simple Cylindrical or Plate Carree. Used for raster maps which store information of the whole world: Each pixel represents a square block of LatLon coordinates, i.e. information is stored per degree, per minute, etc. Used for mapping the earth taken as a sphere.
EquiRectangular	Also called Plate Rectangle. Variant of Plate Carree. Used for raster maps which store information of the whole world: Each pixel represents a rectangular block of LatLong coordinates.
Mercator	Conformal. Designed for navigational use; standard for marine charts. Recommended use for conformal mapping of regions predominantly bordering the equator. Often inappropriately used as a world map.
Trasverse Mercator	Also called Gauss Conformal, or Gauss{xe “Gauss projection\:Kruger”} Krüger. Transverse form of the Mercator Projection (conformal). Used for many topographic maps at scales from 1: 20000 to 1: 250000. Recommended for mapping regions that are predominantly north-south in extent.
UTM	Universal Transverse Mercator. Map is conformal. Widely used for topographic maps and military maps.
Lambert Cylindrical Equal Area	Lambert Cylindrical Equal Area. Mainly used for educational purposes.
Mollweide	Pseudo-cylindrical projection. Map is equal area. Occasionally used in thematic world maps.
Azimuthal	
Lambert Azimuthal Equal Area	Lambert Azimuthal Equal Area. Used for maps of continents and hemispheres. Also suited for regions extending equally in all directions from a center point, such as Asia and the Pacific Ocean.
Azimuthal Equidistant	Azimuthal Equidistant. Commonly used in the polar aspect for maps of polar regions and the Northern and Southern hemispheres. The oblique aspect is frequently used for world maps centered on important cities and occasionally for maps of continents.
Orthographic{xe”Orthographic projection”}	Known by Egyptians and Greeks 2000 years ago. Map is perspective and neither conformal nor equal area. Only one hemisphere can be shown. The earth appears as it would on a photograph from space.
Stereographic{xe”Stereographic projection”}	Apparently invented by Hipparchus (2nd century BC). Used in combination with UTM projection as Universal Polar Stereographic (UPS) for mapping poles and in navigation charts for latitudes above 80°. Recommended for conformal mapping of regions that are approximately circular in shape. For example, used for topographic maps of the Netherlands.
Gnomonic	Map is perspective and neither conformal nor equal area. It is used to show great circle paths as straight lines and thus to assist navigators and aviators.
Conical	
Albers Equal Area Conic	If the pole is one of the standard parallels, it is equal to Lambert’s Equal Area Conic. Frequently used for maps of the United States, for thematic maps and for world atlases. Recommended for equal area maps of regions that are mainly east-west in extent.
Lambert{xe”Lambert\:conf conic projection”} Conformal Conical	Lambert Conformal Conic/Conical Orthomorphic (Lambert, 1972) (conformal). Extensively used for large-scale mapping of regions predominantly east-west in extent. Further widely used for topographic maps.
Equidistant Conic	Also called Simple Conic. The most common projection in atlases for small countries.
Polyconic	or American Polyconic (Hassler, ± 1820). Map is neither conformal nor equal area. The sole projection used for large scale mapping of the United States by the USGS until the 1950’s.

6. Plane rectangular coordinate systems for national use

Rectangular coordinate systems for national use, also called national grid systems, are always based on a particular map projection. A map projection by itself isn't enough to define a national grid system. One has to define e.g. the ellipsoid and geodetic datum, the center of the projection, the scale factor, the origin of the rectangular coordinate system. The most widely used grid system is the so-called UTM system.

6.1 Universal Transverse Mercator (UTM)

UTM stands for Universal Transverse Mercator. It is a version of the Transverse Mercator projection, but one with a transverse secant cylinder (see figure 2).

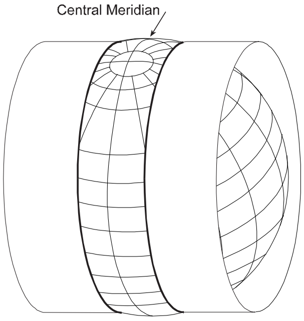

Figure 2 – Transverse secant cylinder

The UTM system is designed to cover the whole world (excluding the Arctic and Antarctic regions). To keep scale distortions in acceptable limits 60 narrow longitudinal zones of 6 degrees longitude in width are defined and numbered from 1 to 60. The figure below shows the UTM zone numbering system. Shaded in figure 3 is UTM grid zone 3 N which covers the area 168° – 162° W (zone number 3), and 0° – 8° N (letter N of the latitudinal belt).

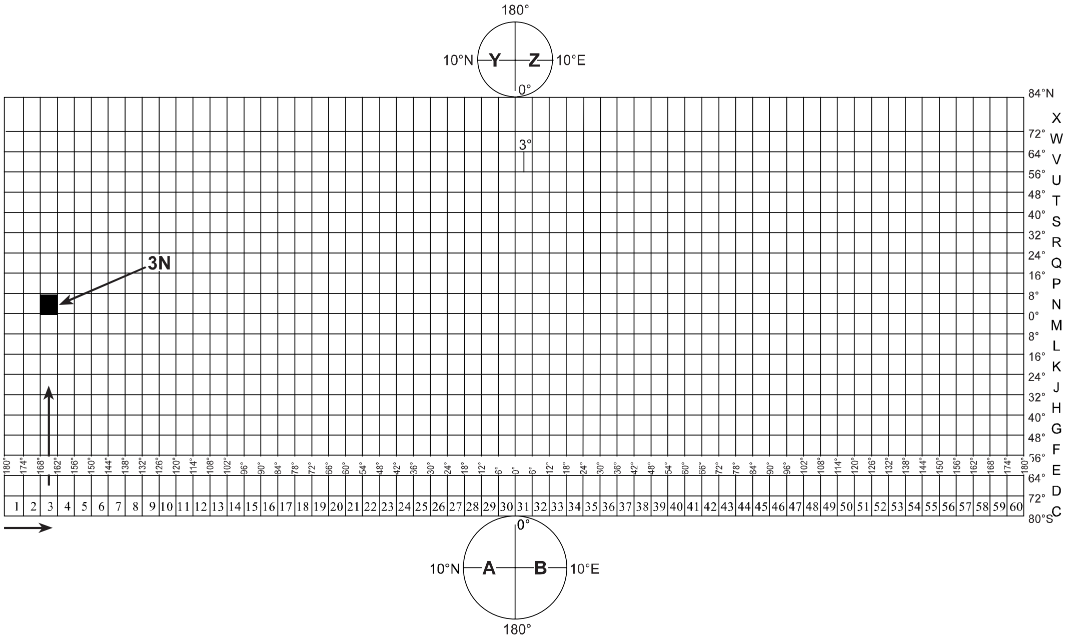

Figure 3 – Representation of the earth on the UTM projection

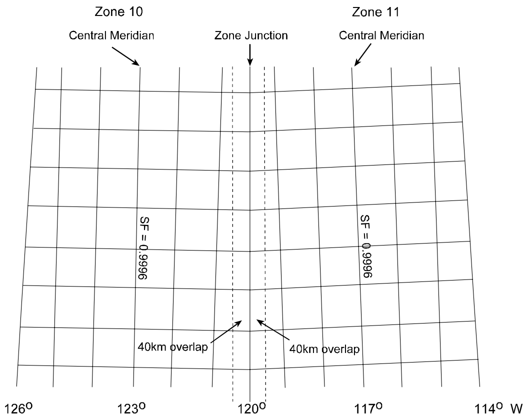

Figure 4 – two adjacent UTM-zones of 6 degrees longitude

The central meridian has been given an Easting value of 500.000 m (to avoid negative coordinates). For mapping north of the Equator, the Equator is given a Northing value of 0 m. For mapping south of the Equator, the Equator is given a Northing value of 10.000.000 m.

Unfortunately, not all countries adopted the UTM grid system. Parameters of the grid systems applied in the Netherlands, Germany and France are given below. In addition to the projection parameters, datum parameters are specified. A geodetic (or horizontal) datum is defined by the size and shape of an ellopsoid as well as several known positions on the physical surface at which latitude and longitude measured on that ellipsoid are known to fix the position of the ellipsoid.

Country: *The Netherlands*	
	Projection system
Projection:	**Double stereographic (or Schreiber)** *(Rijksdriehoeksstelsel)*
Zone(s) (if applicable):	N/a
Limits of zone(s) (if applicable):	N/a
Latitude of projection origin (φ_0):	52:09:22.178 d:m:s
Longitude of projection origin (λ_0):	*5:23:15.500 d:m:s*
Scale factor at projection origin:	0.9999079
False easting (m):	155 000 m
False northing (m):	463 000 m
	Geodetic datum
Datum name:	Rijksdriehoeksmeting
Ellipsoid name:	Bessel 1841
Semi-major axis of ellipsoid (a):	637739.155000 m
Semi-minor axis of ellipsoid (b):	–
Flattening of ellipsoid:	1/299.152813
Fundamental point:	Amersfoort φ = 52° 09’ 22”. 178 λ = 5° 23’ 15”. 500
Orientation:	Not known
Datum shift in X (m):	565.04 m
Datum shift in Y (m):	49.91 m
Datum shift in Z (m):	465.84 m
Rotation in X (α):	*0.4094”*
Rotation in Y (β):	*0.3597”*
Rotation in Z (γ):	*1.8685”*
Scale (s):	*4.0772 ppm*
	Vertical datum
Datum name:	Normaal Amsterdam Peil (NAP) , Mean Sea Level at Amsterdam

Country: *Germany*	
	Projection system
Projection name:	**Transverse Mercator (or Gauss-Krüger)**
Zone(s) (if applicable):	3 zones with central meridians at 6°, 9° and 12°
Limits of zone(s) (if applicable):	Width of the zones 3°
Central meridian (λ_0):	6°, 9° and 12°
Scale factor at Central Meridian:	1.00000
Latitude of origin (φ_0):	0° (equator)
Scale factor at latitude of origin (k_0):	N/a
False easting (m):	500.000 m
False northing (m):	0 m
	Geodetic datum
Datum name:	Potsdam
Ellipsoid name:	Bessel
Semi-major axis of ellipsoid (a):	6377397.155 m
Semi-minor axis of ellipsoid (b):	6356078.963 m
Flattening of ellipsoid:	–
Fundamental point:	Rauenberg φ = 52° 27’ 12”. 021 λ??= 13° 22’ 04”. 924
Orientation:	Azimuth to Berlin, Marienkirche = 19° 46’ 04”. 87
Datum shift in X (m):	586 m
Datum shift in Y (m):	87 m
Datum shift in Z (m):	409 m
Rotation in X (a):	*0.52”*
Rotation in Y (b):	*0.15”*
Rotation in Z (g):	*2.82”*
Scale (s):	*9 ppm*
	Vertical datum
Datum name:	**DHHN**

Remarks

DHHN: Normal orthometric heights based on NN (Normal Null), the mean sea level at Amsterdam.
For the five eastern German states heights are also based on the mean sea level at Kronstadt (difference between DHHN and eastern German normal heights up to 8–15 cm.

Country: *France* Region: *Provence*	
	Projection system
Projection name:	**Lambert Conformal Conic**
Zone (if applicable):	Lambert zone III
Limits of zone (if applicable):	47gr – 50.5gr
1st standard parallel (φ1):	43° 11’ 57.44859”
2nd standard parallel (φ2):	44° 59’ 45.93773”
Scale factor at standard parallel(s):	Unknown
Central meridian (λ_0):	2° 20’ 14.02500” (6^{gr})
Latitude of origin (φ_0):	44° 06’ (49^{gr})
Scale factor at latitude of origin (k_0):	0.99987750
False easting (m):	Lambert III Sud: 600000 m Lambert III Carto: 600000 m
False northing (m):	Lambert III Sud: 200000 m Lambert III Carto: 3200000 m
	Geodetic datum
Datum name:	Nouvelle Triangulation de la France (NTF)
Ellipsoid name:	Clarke 1880 IGN
Semi-major axis of ellipsoid (a):	6378249.2000 m
Semi-minor axis of ellipsoid (b):	6356515.0000 m
Flattening of ellipsoid:	1/293.466021
Datum shift in X (m):	–168 m
Datum shift in Y (m):	– 60 m
Datum shift in Z (m):	+320 m
Rotation in X (α):	*0”*
Rotation in Y (β):	*0”*
Rotation in Z (γ):	*0”*
Scale (s):	*1 ppm*
	Vertical datum
Datum name:	**MEAN SEA LEVEL AT MARSEILLE**
Remarks *Mean sea level heights are approximate +8 m above the Clarke 1880 IGN ellipsoid in Goult area*	

For more information on coordinate systems refer to:
http://kartoweb.itc.nl/geometrics