An Introduction to Coordinate Systems in South Africa

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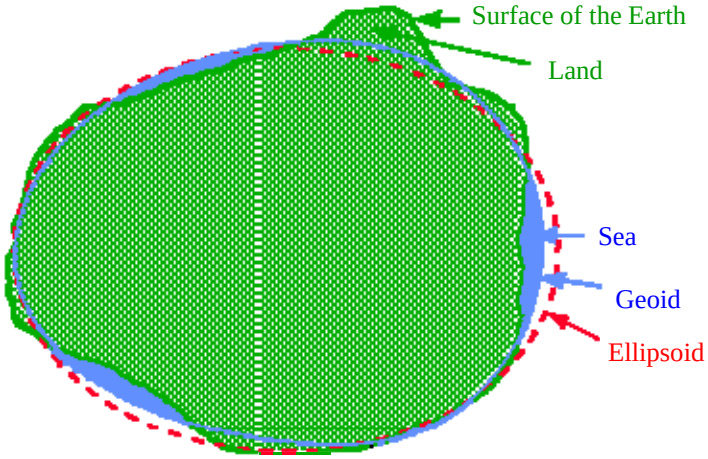
Centuries ago people believed that the earth was flat and notwithstanding that if this had been true it would have produced serious problems for mariners sailing off to explore the world it would nevertheless have made life a lot simpler for surveyors in preparing maps.

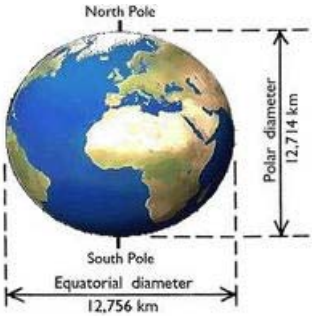
Unfortunately for us the earth is an irregular shape which is roughly spherical. The figure below illustrates this irregularity (land areas in green and seas in blue).

Model of the Earth



Mathematicians need to define a theoretical surface on which to base calculations. The figure most commonly used is the ellipsoid (imagine a sphere which has been flattened at the poles). This is represented on the figure to the left by a red dotted line.

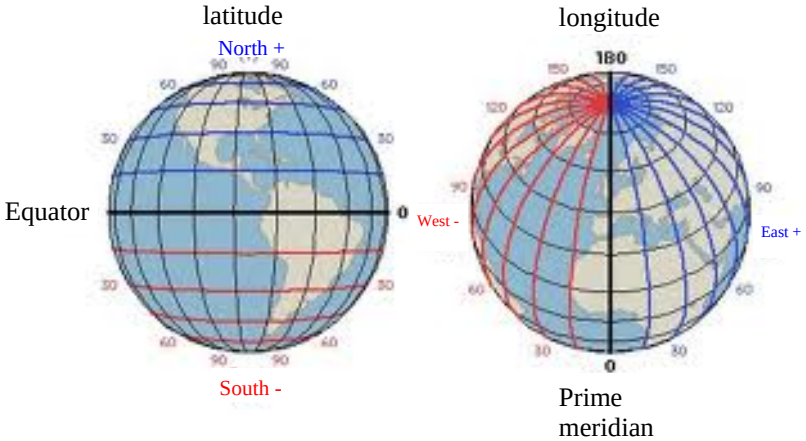
You can see this polar flattening in the globe on the right

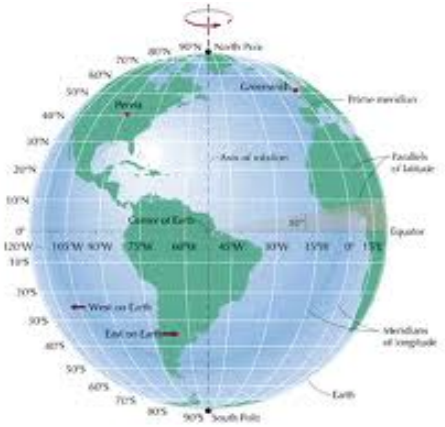


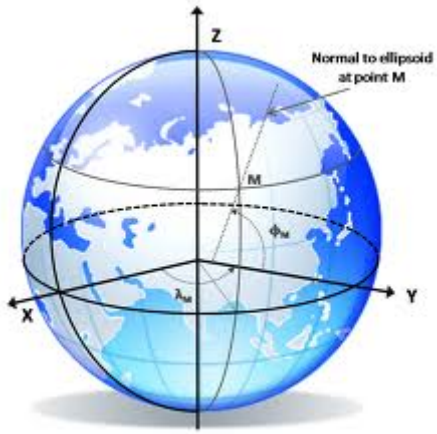
Once an ellipsoid has been defined, lines of latitude and longitude can be generated for that ellipsoid.

Lines of longitude are great circles which pass through both the north and south poles. 0° longitude passes through the Greenwich observatory in London, England. Values of longitude (0° to 360°) increase in an easterly direction around the globe. Longitude 31° east passes directly through Durban (and also Harare in Zimbabwe and Cairo in Egypt).

Lines of latitude are defined a right angles to lines of longitude. The largest such line is equidistant from both the north and south poles and is defined as the equator at 0° latitude. Values north of the equator increase positively to 90° at the north pole and values south of the equator increase positively to 90° at the south pole (southerly latitude values sometimes are given negative values).

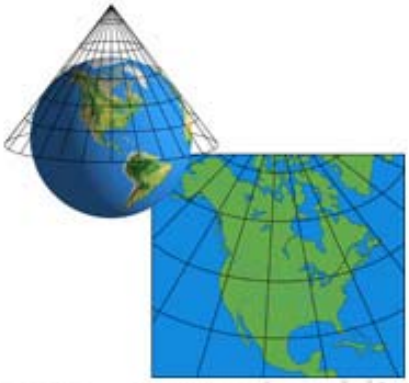




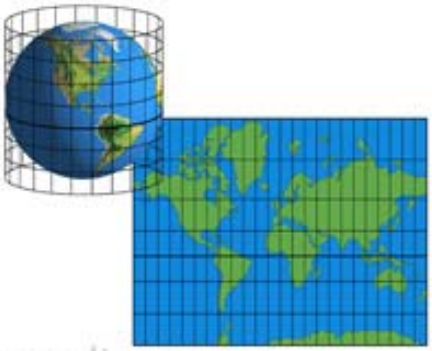


It is important to note that values of latitude & longitude are angles subtended from the centre of the defined ellipsoid and as such are complicated to work with for survey calculations. The vast majority of maps and plans are two dimensional and what is needed are values which define two dimensional position - for example values of Y and X.

To do this, ellipsoidal values need to be "projected" onto a plane surface using simple shapes as illustrated below. The type of projection chosen is dependant on the shape and position of the area to be mapped. The idea is to project with minimum distortion but we must understand that no projection will be perfect - imagine pealing an orange and trying to press the peal onto a flat surface without tearing it.

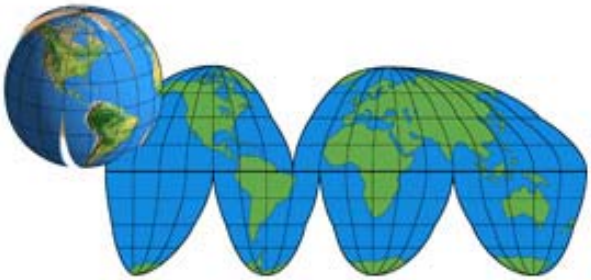


conic projection



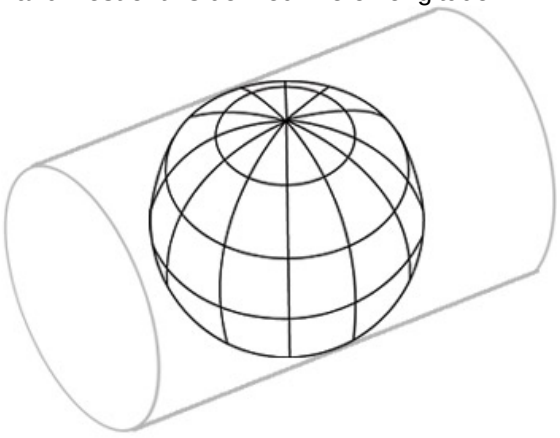
cylindrical projection

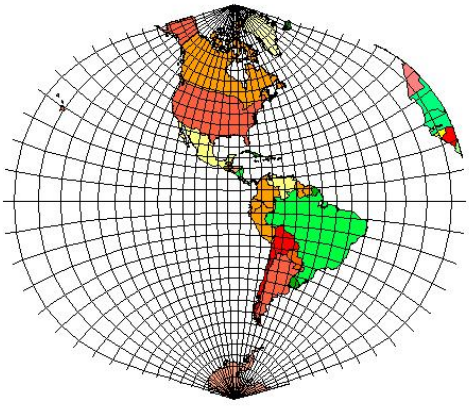
plane projection



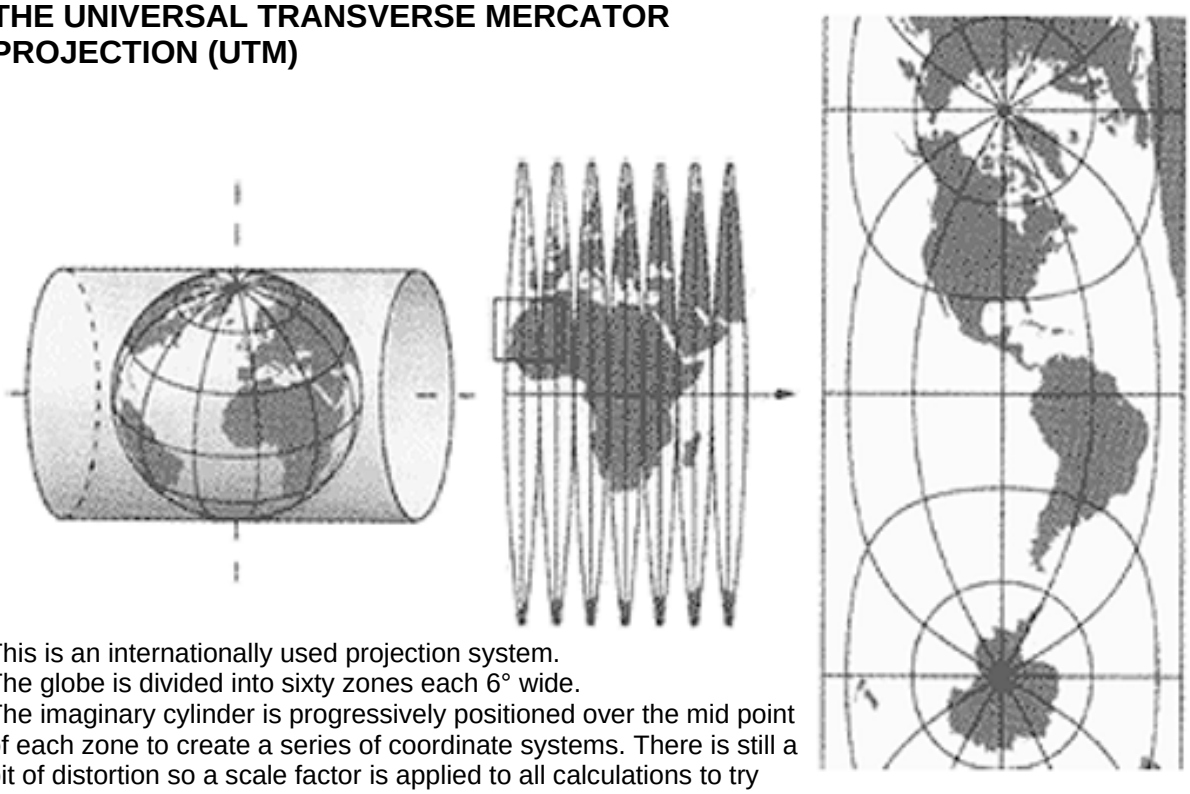
interrupted projection

A common type of projection used world wide is the "Transverse Mercator Projection". It is a variation of the cylindrical projection shown above but the imaginary cylinder is positioned in contact with a defined line of longitude. You can see from the illustration below right that distortion occurs both east and west of this defined line of longitude.





THE UNIVERSAL TRANSVERSE MERCATOR PROJECTION (UTM)

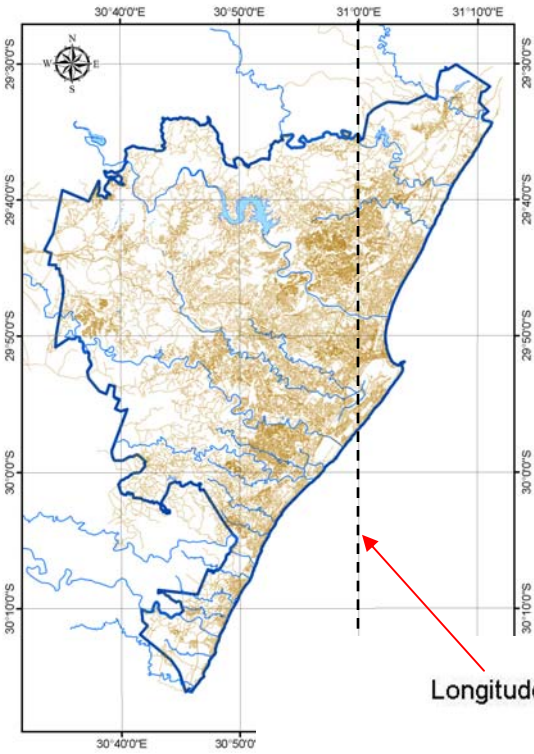


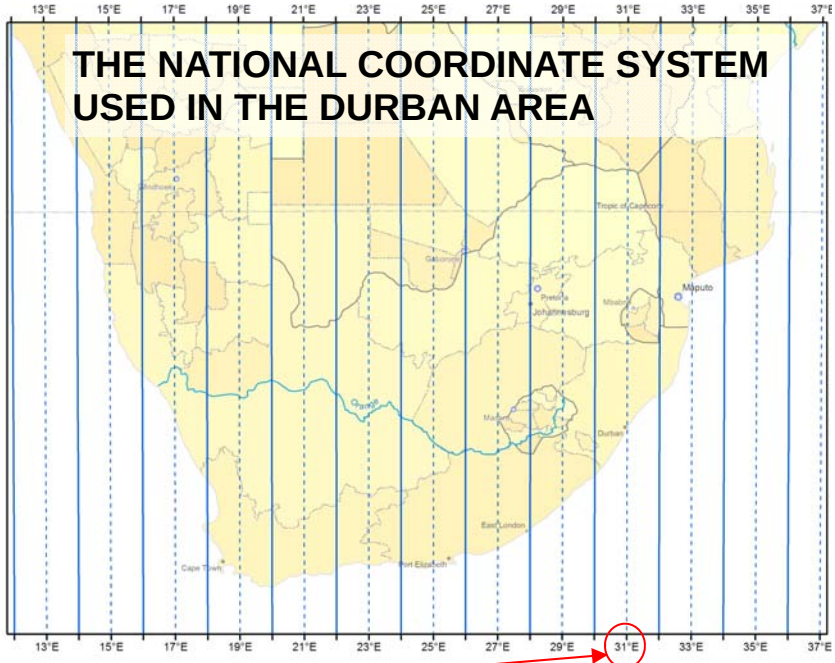
This is an internationally used projection system.
The globe is divided into sixty zones each 6° wide.
The imaginary cylinder is progressively positioned over the mid point of each zone to create a series of coordinate systems. There is still a bit of distortion so a scale factor is applied to all calculations to try and minimize this.

SOUTH AFRICA'S NATIONAL COORDINATE SYSTEM

In South Africa, a variation of the UTM projection called the "Gauss Conformal Projection" is used to define our national coordinate system. The principles of the projection are the same but each zone is only 2° wide (as opposed to 6° wide). There is less distortion and no scale factor is required. Longitudes 17°East, 19°East, 21°East, 23°East, 25°East, 27°East, 29°East, 31°East and 33°East are used as the mid-points of each 2° projection.
These coordinate zones were referred to as Lo17, Lo19, Lo21 ..etc (Cape Datum) until 1999 when the national system changed from one based on the Clarke 1880 modified ellipsoid to the more internationally recognised WGS84 ellipsoid.
The coordinate zones are now referred to as Wg17, Wg19, Wg21 ..etc (Haartebeeshoek 1994 datum).
The coordinate zone in use in the Durban area is Wg31 because as mentioned earlier, longitude 31° east runs directly through the city.

THE NATIONAL COORDINATE SYSTEM USED IN THE DURBAN AREA





Longitude = 31° east

Equator : latitude = 0°

1° 1° X = 0 metres

WG31° origin

Y values increase positively

Y values increase negatively

Y = 0 metres

UTM ZONE 36

Programmes such as ArcView interpret Y and X values in UTM orientation as shown below in blue.
This is why coordinates in our National System have to appear reversed and of opposite sign in order for their relative positions to be viewed correctly in ArcView.
ie X(ArcView) = -Y(wg31) and
Y(ArcView) = -X(wg31) PTO for more ...

Northings/ Y values increase positively

UTM origin
Northing /Y = 0
Easting/X = 0

Eastings/ X values increase positively

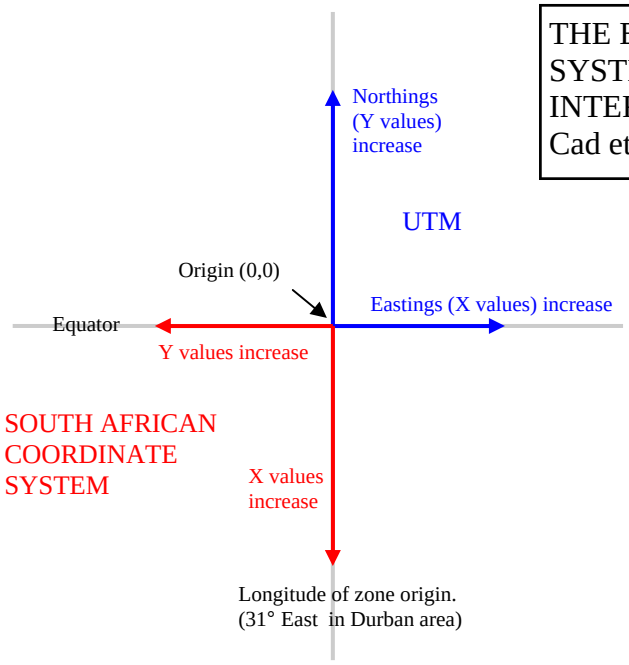
X values increase positively

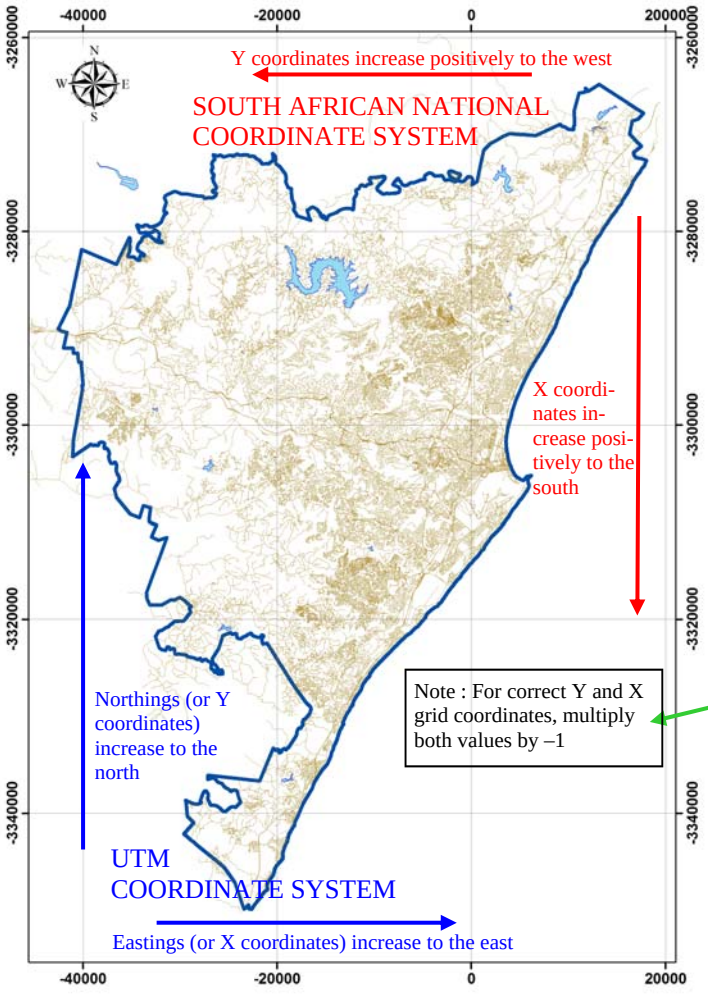
South Pole

Directions
Angles of direction increase positively in a clockwise direction.
The direction 0° points south

Distortions
Distortion increases with distance away from the central meridian (longitude 31° east) .This affects both distance and direction measurements.
Corrections have to be applied to their values to enable accurate calculations of both Y and X coordinates.

THE EFFECT ON SOUTH AFRICAN NATIONAL SYSTEM COORDINATES WHEN USED IN INTERNATIONAL SOFTWARE ie ArcView, Auto-Cad etc





International software such as the ESRI products (ArcGIS etc) and AutoDesk products (AutoCad etc) interpret coordinate values
in Universal Transverse Mercator (UTM) orientation as shown in blue to the left.
UTM values are referred to as Eastings and Northings (X's & Y's).

South African National Coordinates (SA) are referred to as Y's and X's .
If our SA values are simply entered without correction, then the software will interpret our Y's as Northings and our X's as Eastings
ie Y values(SA) are read as Y values (UTM) and are therefore increasing positively northwards instead of westwards AND X values(SA) are read as X values (UTM) and are therefore increasing positively eastward instead of southward - all relative to the coordinate origin which is the Equator and the central meridian of the coordinate zone (which in the Durban area is longitude 31° East).

It may be possible in some software to enter the necessary predefined coordinates systems within "coordinate settings" options, but if not, in order to view South African National Coordinate System values in their correct relative positions , it is necessary to enter their values as follows:
X value (UTM) = Y value (SA) x(–1)
Y value (UTM) = X value (SA) x(–1)

Although relative position is now correct,
It should be noted that the displayed coordinates will still have opposite signs and maps produced with grid values will reflect this as seen on the map to the left. All maps produced using this software and displaying coordinate grid values, should therefore include an explanatory note referring to this. An example appears on the map to the left.

ArcView ver10 now has settings which enable South African system coordinates and grid values to be viewed correctly but be aware that all datasets used in GIS software should have coordinate systems defined. If not, they may not display correctly.

Should anyone require advice or clarity on any aspect of the use of coordinates in general, please do not hesitate to contact the writer or the Land Surveying Branch of the Surveying & Land Information Department.