Humanitarian Field Guide to GNSS Technology

Abstract

This guide provides advice on the hands-on application of GNSS units, computer-based technology and georeferenced maps (digital and hardcopy) in the humanitarian field. It includes a list of web resources that provide maps and related software.

References

Items marked [A1] or [A2] are listed in the appendices.

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1.0 GNSS basics

A Global Navigation Satellite System, GNSS is a set of satellites that transmit data to enable a GNSS receiver to determine its geographical position. Currently there are three major operating systems – GPS (USA), GLONASS and Galileo. Other GNSS systems are operating but are not generally suitable for universal use. Provided a GNSS receiver has a clear view of the sky it is effective anywhere on the earth's surface at any time. The GNSS location can be degraded inside buildings, by very dense foliage or by the proximity of solid structures such as buildings or cliff faces.

The term dilution of precision, DOP, refers to loss of accuracy due to shortcomings in the location determining process (particularly satellite number and placement – the constellation). It may be subdivided into position DOP, PDOP, horizontal DOP, HDOP and vertical DOP, VDOP components. Lower values are desirable – 2 is good, 10 is moderate.

Handheld GNSS units have the facilities to manage waypoints and tracks. Some GNSS units have the ability to display maps. Smart phones and like devices commonly have GNSS capability and can run software to enable user interaction.

When appropriate in this document the technically correct term, GNSS, will be used rather than the possibly more common, but less correct, term, GPS.

1.1 Waypoints:

A waypoint (also known as point of interest, POI) is a recorded location. A waypoint can be recorded in a GNSS unit by
- marking the current location,
- keying in a location reference or
- downloading a location reference from a computer.

The GNSS unit can be used to navigate to a waypoint location. Waypoints can be uploaded to a computer.

1.2 Tracks:

A track is a recorded path. A track can be recorded in a GNSS unit by
- moving with the GNSS unit active or
- downloading the track from a computer.

The GNSS unit can be used to guide the user along a track. A track can be uploaded to a computer.

2.0 Scale

In the case of a hard copy map, the scale, when expressed as a ratio, "1:100,000" for example, is unambiguous – 1 cm on the map represents 1cm X 100,000 = 1.000 km on the ground. In the case of an electronic map image, the situation is not as straightforward. On a laptop, a map image file with a ground extent of 25 km may be displayed as 250 mm wide (a scale of 1:100,000), while the same file presented on a video projector screen may be ten times the size (a scale of 1:10,000). Similarly a map file printed on an A4 sheet will be at a different scale to the same file printed on an A3 sheet. A scale bar, however, remains valid at any degree of enlargement.

Fig. 1 Scale bar on UNOSAT map

Larger scale maps, for example a MapAction [A2] map of an IDP camp, show more detail of a smaller area; smaller scale maps, for example a Logistics Cluster [A2] transport routes map, show less detail over a larger area.
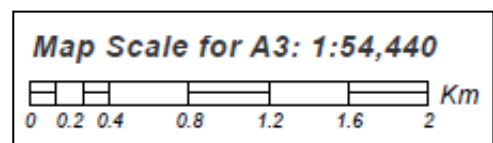
3.0 Coordinate systems

A geographic location is specified by a reference within a coordinate system. The two common coordinate systems are latitude and longitude (also known as geographic) and UTM/UPS (often known simply as UTM).

3.1 Latitude and Longitude coordinate system:

The geographical coordinate system is useful on small and medium scale maps; it is not as convenient as the UTM system on large scale maps. The parallels of latitude run east-west, the meridians of longitude run true north-south from pole to pole. A location is given by the latitude north or south of the equator and the longitude east or west of the zero meridian. The units are generally degrees, minutes and seconds, though there are format variations. There are 60 seconds in a minute and 60 minutes in a degree. A negative sign on latitude can be used to indicate south, a negative sign on longitude can be used to indicate west.

A location in Sydney	A location in Dublin	Format
– 33.8700°, 151.2183°	53.3345°, – 6.2508°	D.dddd
– 33° 52.20', 151° 13.10'	53° 20.07' N, 6° 15.05' W	D M.mm
33° 52' 12" S, 151° 13' 6" E	53° 20' 4", – 6° 15' 3"	D M S.s

Fig. 2 Some examples of latitude, longitude formats.

A degree of latitude or a degree of longitude at the equator is approximately 110 kilometres; a minute of latitude or a minute of longitude at the equator is approximately 1.9 kilometres – a nautical mile.

3.2 UTM/UPS:

The Universal Transverse Mercator/Universal Polar Stereographic, UTM/UPS, or UTM coordinate system is convenient for medium or large scale maps. The world is divided into 60 longitudinal zones (notated by a *zone number*, 0 – 59) by meridians spaced at 6 degree intervals (0°, 6°, 12°, ...). On each of these zones a square grid is projected. In addition there are 20 lateral zones (notated by an alphabetical *zone characters*). A location reference on this grid is specified by a *zone number*, a *zone character*, an *easting* (6 digits) and a *northing* (7 digits, though just north of the equator the northing may have leading zeros).

The UTM system uses the alphabetic characters **C** through to **X** excluding **I** and **O** but including **N** and **S** as lateral zone indicators. However in some UTM system applications the symbols **N** and **S** serve as hemisphere designators as an alternative for zone indicators. A general rule is – do not substitute **N** and **S** for zone indicators unless explicitly required.

Fig. 3 Allocation of characters in UTM reference

The UTM system can be useful on medium and large scale maps because the coordinates are metre based and a grid overlay is square and regular – commonly 1 kilometre. Plane geometry techniques can be used if calculating distance and area. Complications can occur if a map contains a zone boundary.

If a map is marked with a 1 kilometre grid it may be the practice in a radio net to give local locations as a *6 digit grid reference*. The appropriate numerals are underlined in Fig. 3.

The UTM grid is aligned to *grid north*. The difference between grid north and true north is termed, convergence, and is location dependent ranging from -3° to +3°, with the smaller values for locations near the equator.

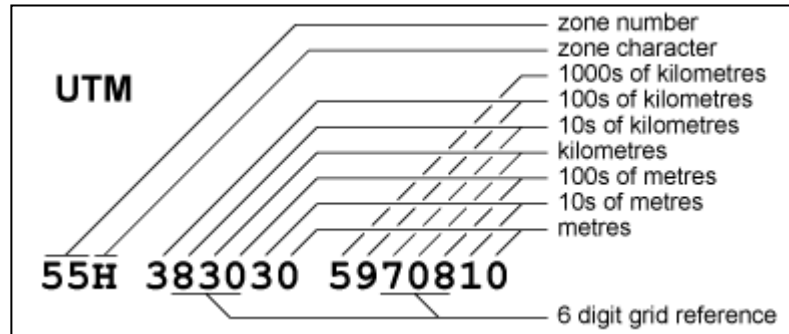## 3.3 Coordinate Conversion:

Computer programs that are intended for GNSS unit interfacing (for example, GPS Utility [A1] and OziExplorer [A1]) can be used to convert between coordinate systems. GPS Visualizer [A1] is a versatile online coordinate converter.

4.0 Datum

Traditionally the zero meridian of longitude passes through a brass marker at Greenwich (actually the precise location is approximately 100 m to the east) – the marker is the reference for the traditional geographic coordinate system. In an analogous fashion there is a reference – a datum – for global positioning systems – in fact for historical and other reasons there are many references. Fortunately the World Geodetic System 1984, **WGS 84**, is dominant internationally. Wherever a datum choice is presented choose WGS 84.

5.0 KMZ and KML files

KML (Keyhole Markup Language) files can carry global position data and references to other files (typically graphics files) in a markup language format (for example,such as HTML) and as a result they are text based. Thus a KML file on its own could contain a set of waypoints but not an associated map image. Any map image would be on a separate file.

A KMZ (Keyhole Markup Zip) file is a zipped compilation of a KML file and any associated files. The zipping and unzipping processes are generally performed by the application programs and are transparent to the user.

KMZ files can be displayed in Google Earth Pro [A1] and loaded into some map-capable GNSS units. User generated Google Earth Pro data can be saved as a KMZ file.

6.0 GPX files

GPX files carry GNSS data (waypoints, routes, and tracks) in a text based markup language. The GPX format provides a standard that allows the exchange of GNSS data across platforms and devices.

GPX files can be displayed in Google Earth Pro and loaded into GNSS units.

7.0 KMZ and GPX files on handheld GNSS devices

Some Garmin GNSS units including the Oregon, Dakota, Colorado, eTrex 20 and eTrex 30 models (see Devices Compatible with Custom Maps) will load and display KMZ files containing map graphics. KMZ files can be loaded into the *Garmin\CustomMaps* folder in the same manner as files can be manipulated on a USB memory stick. Note, typically only the graphical data (a map), not any global position related data (waypoints, tracks or routes) that the KMZ file might contain are loaded by this process. Global position data generally must be loaded separately as a GPX file. For Garmin units GPX files carrying waypoint data can be loaded into the *Garmin\GPX* folder. After a Garmin unit is restarted the KMZ files will appear on the map list and may be enabled or disabled by the user. Some GNSS units have a map display quality option; this item should be set to maximum.

KMZ files with map images intended for handheld devices are usually tiled. The map image is comprised of sections, or tiles (Garmin sometimes calls them 'images'). GNSS units may have a constraint on the maximum number of tiles they can load. Garmin map-capable units produce a message *too many custom map images, they will not be displayed* on start-up if the total tile complement exceeds the limit.

The number of tiles in a KMZ file can be determined by expanding the file into its descendants in the places section of the Google Earth Pro sidebar. Large KMZ map files may have a tile count in excess of the limitations of the GNSS unit. It is possible in Google Earth Pro to delete individual tiles to bring the tile count within the bounds of the GNSS unit. The modified file must be saved before loading into the GNSS unit.

Fig. 4 is a screen shot from a Garmin GNSS unit loaded with a KMZ map file. The waypoints (ID-6, ID-11, ID-13) were loaded with a GPX file.

Fig. 4 GPS screenshot

A user may generate position data on Google Earth Pro (tracks, routes, waypoints) and then wish to load these data into a GNSS unit. It may be necessary to convert a KMZ file (saved from Google Earth Pro) to a GPX format. GPS Utility [A1] will convert KMZ and KML files to GPX files, OziExplorer [A1] will convert KML files. GPS Visualizer [A1] is a versatile online file format converter.
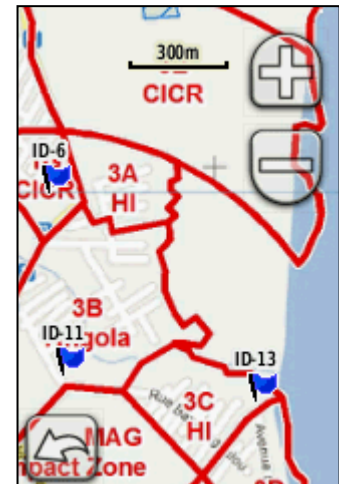
8.0 KMZ files, GPX files, GNSS data and Google Earth Pro

8.1 Opacity Control
A KMZ file will open in Google Earth Pro as an overlay. The transparency (or its complement, opacity) of a map image can be controlled with the slider at the base of the "Places" box in the side bar. Many KMZ maps are tiled. Map tiling can be exposed by expanding the map reference in the side bar and the tile transparency individually managed. KMZ maps may be overlayed one on another and alignment of features can be checked by use of the transparency slider.

8.2 Loading GNSS data
GNSS data (waypoints, tracks, route) may be directly loaded into Google Earth Pro from the GPX unit but a more secure method is to first save the GNSS data as GPX files and then load those files into Google Earth Pro through the "File → Open" menu (select files of type "Gps"). If there are data missing, try adjusting the history bar which may have appeared in the top left corner of the Google Earth Pro screen.
Google Earth Pro provides documentation capacity. Areas can be outlined, placemarks and images inserted. It is an effective process once the user becomes familiar with it. Support material is available on the web.
The total data displayed in the Google Earth Pro window (say – UNOSAT map, waypoints imported from GNSS unit, placemarks) can be saved as a single KMZ file for record keeping and distribution.

9.0 Navigating with personal smart devices

9.1 Principal Requirement
In locations where the smart device (mobile phone or tablet) cannot interact with phone towers or Wi-Fi networks then the device must have an inbuilt GNSS receiver if it is to provide secure navigation data. (The term, GNSS onboard, is sometimes used.)   It could prove useful for you to know if your device has a GNSS receiver. If in doubt check the device specifications or seek advice. Apps are available that provide information about the presence and performance of an onboard GNSS receiver. MapToGround found GPSTest [A1] to be very effective when tested on an Android tablet.
(A similar situation exists with magnetic sensors for applications requiring direction data. Not every smart device has a suitable magnetic sensor. There are some applications that work around this deficiency with mixed success by using GNSS data to determine direction. The arrangement is satisfactory when the user is moving but lacking utility when the user is stationary,)

9.2 Navigation Assistance Software
The range of navigation apps that can be obtained for personal smart devices is extensive, and a potential user could spend a considerable amount of time investigating different options. Relevant field advice for a particular assignment could be very valuable. There are two broad classes of mapping apps. One class uses dedicated base maps, for example Google Maps or apps utilizing OpenStreetMap. Apps in the other class provide a selection of maps and also permit the loading of custom maps. Examples of the latter class are Avenza Maps [A1] and OziExplorer for Android [A1].
Another consideration when selecting a mapping app is the ability (or not) of the app to function without internet connection.

9.3 Creating a Custom Map
Producing a georeferenced map of a remote location to run on a personal smart device is not a trivial exercise. The OziExplorer [A1] method would be a reasonable choice for the task as it is flexible in the range of image files and coordinate systems it can work with. If there is a method for generating geo-TIFFs or geo-PDFs available then the Avenza [A1] route may be more straightforward though the outcome will have less utility. If it is necessary to convert a PDF file to one of the standard raster formats or vice versa it is likely that you will find a convertor online.

A1: Map and GNSS software resources

ArcGIS Explorer, www.esri.com/software/arcgis/explorer
ArcGIS Explorer is a free GIS Viewer that enables the user to explore, visualize, and share GIS information. The user can create custom maps, include local data and perform spatial analysis.

Avenza Maps www.avenzamaps.com
Avenza is a mapping app for Android devices. It does not require an internet connection to work. The user can choose maps from a very large range of maps. It will load custom maps in a georeferenced TIF format.

Earth Point, www.earthpoint.us/
Earth Point provides useful online tools, in particular a versatile coordinate converter.

EasyGPS, www.easygps.com/
EasyGPS is free software for laptops, tablets, and desktop computers running Windows 7, 8, and 10. It exchanges GNSS data with GNSS units. It has useful GPX data management and editing features.

Goggle Earth Pro, https://www.google.com/earth/versions/#earth-pro
Goggle Earth Desk will import an extensive range of file types and generates and exports KMZ files.
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GPSTest, github.com/barbeau/gpstest
GPSTest (Sean Barbeau) is a comprehensive GNSS test application for phones and tablets running the Android operating system.

GPS Utility, www.gpsu.co.uk
GPS Utility is a freeware program for GNSS receiver interaction. It manages, manipulates and maps waypoint, route and track information. It handles (and hence can convert) an extensive range of file formats.

GPS Visualizer, www.gpsvisualizer.com
GPS Visualizer provides online file conversions and displays uploaded GNSS data.

ICSM, Fundamentals of Mapping, http://www.icsm.gov.au/education/fundamentals-mapping
ICSM provides a comprehensive overview of maps, mapping, cartography and map production. It is covers mapping concepts, principles and practice.

IrfanView www.irfanview.com/
IrfanView is a Windows platform image manipulation program with broad features. It can load/save an extensive range of file types.

Mapwel, www.mapwel.net/
Mapwel provides a moderate cost program for constructing IMG and KMZ files from an extensive range of sources and for comprehensive interaction with Garmin GNSS receivers.

OziExplorer, www.oziexplorer4.com/au/
OziExplorer GNSS mapping software runs on Windows platforms and Android devices. It interacts with external or onboard GNSS receivers for real time tracking and uploading/downloading of waypoints, routes and tracks. Custom maps can be created from raster files provided georeferencing data are available.

Quantum GIS, qgis.org/en/site/
QGIS is a free Geographic Information System that enables the user to create, edit, visualise, analyse and publish geospatial information on Windows, Mac, Linux, BSD and Android platforms.

A2: Map resources

CIA World Factbook, https://www.cia.gov/the-world-factbook/
 The CIA World Factbook provides country, regional and physical and political world maps.

GDACS, vosocc.unocha.org/
 GDACS, "virtual OSOCC", is a cooperation framework between the United Nations, the European Commission and disaster managers worldwide to improve alerts, information exchange and coordination in the first phase after major sudden-onset disasters.

iMMAP, immap.org/
 iMMAP is an organization that provides information management services to humanitarian and development organizations. Maps present management data rather than topographical material.

Logistics Cluster, www.logcluster.org/
 The WFP Logistics Cluster provides an extensive range of maps in PDF and/or PNG format intended for humanitarian logistics application. The *General Logistics Planning Maps* provide country wide coverage.

MapAction, https://www.mapaction.org/
 MapAction's range of maps is extensive; the maps are generally directed towards operational issues such as logistics and population movement. MapAction also provides PowerPoint map templates and map symbol sets to enable the production of PowerPoint material for report presentation.

MapToGround, maptoground.ccmaps.au
 MapToGround provides maps from recognized humanitarian sources as KMZ files. geotiff files and OziExplorer support files. It also provides technical support material for workers in the humanitarian field.

OpenStreetMap, www.openstreetmap.org/
 OpenStreetMap is a free map of the whole world. Users may edit the map to maintain currency.

ReliefWeb. reliefweb.int/countries
  Maps and infographics are available via the country directory of ReliefWeb. ReliefWeb is a digital service of the United Nations Office for the Coordination of Humanitarian Affairs (OCHA). It provides disaster and crisis updates and analysis.

UN Cartographic Section, www.un.org/geospatial/
 United Nations Geospatial Network provides general country or region maps, mission maps, latest deployment maps and political operation maps in PDF format. It also provides a world map structured by country in PDF format.

UNITAR, www.unitar.org/
 UNITAR provides an extensive range of map services. To list the services use the on-site search facility with "maps" as the search term.