Transforming GPS to/from UTM Coordinates UWSEA-DUM-94-1
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SUMMARY: This note serves as documentation for Program GPSUTM.pas, as well as providing a description of the GPS and UTM coordinate systems, and a table of surveyed coordinates in both systems for DUMAND equipment deployed in the 12/93 cruise.

I. Geodetic coordinates

Geodetic coordinates are latitude and longitude (conventionally reported as degrees/minutes.decimal by GPS receivers, or degrees/minutes/seconds.decimal by atlases, etc) on the regular biaxial ellipsoid which is used to model the irregular shape of the earth's mean sea-level geopotential surface (the geoid). Deviations between the geoid and the reference ellipsoid are typically less than a few meters at sea. The reference ellipsoid is defined by its semi-major axis a and its flattening f=(a-b)/a. The current standard is the Geodetic Reference System 1980 (GRS-80) which is equivalent to the World Geodetic System 1984 (WGS-84), with a=6378137.0 m, and 1/f=298.2572221.

The astronomic latitude of a given location on the earth is defined as the angle between the plane of the equator and local gravity (plumbline direction). Note that the plumbline direction is the vector sum of the gravitational force (directed to the center of the earth), the centrifugal pseudoforce due to earth rotation, and any local gravitational anomalies, so it does not in general point to the geometric center of the earth.

The astronomic latitude in turn differs from the geodetic latitude, which is the angle between the plane of the equator and the local normal to the ellipsoid. This difference is generally less than 3 seconds of arc. It is geodetic latitude which is reported by a GPS receiver.

II. UTM coordinates

The Universal Transverse Mercator system is a method standardized by the US Army for transforming geodetic coordinates from the ellipsoid into cartesian coordinates on planar maps with error held to 1 part in 10000 or better. Thus, for example, displacements or azimuths measured on a UTM map covering a 10 km square should correspond to measurements on the earth's surface to within 1 m. The UTM system provides a universal, consistent procedure for deriving planar coordinates from geodetic coordinates and vice versa. It is a generalization of the systems developed by individual US states for legal surveying (State Plane Coordinates). The UTM system is only used between latitudes 84N and 80S, where convergence of meridians is managable; the Universal Polar Stereographic projection (UPS) is used for polar regions.

In the familiar schoolbook Mercator projection, the equator is the only standard line (ie, line with scale factor 1.00), with meridians drawn perpendicular to it and equally spaced. Latitude lines are drawn parallel to the equator and spaced to make the projection conformal (ie, equal scale factors in all directions at a given point, so that circles map to circles). It is in fact not a projection but a transformation algorithm. In Transverse Mercator projections, the standard line is a selected meridian rather than the equator. Such a mapping is useless for large areas of the earth, but for small regions provides a map which is conformal, has meridians and parallels perpendicular, and a reasonably constant scale factor over the map area.

The UTM system divides the earth's surface into 60 meridional zones 6 degrees wide, starting at longitude 180W. Each zone is in turn divided into rows which span 8 deg in latitude, lettered from C at lat 80S to X at lat 72N (skipping O and I). Thus the DUMAND site lies in standard UTM Zone 4 (162W--156W), grid quadrangle 4Q. For each zone, one imagines a cylinder pinned to the surface at the central meridian (eg, 159W for Zone 4). Actually, the UTM system places the central meridian below the spheroid surface, with scale factor 0.9996, and the standard lines (scale 1.00) are grid lines 180000 meters east and west of the origin. Within a quadrangle, locations are given in cartesian coordinates in meters, with x and y referred to in surveying jargon as the "easting and northing". To keep grid coordinates positive, the central meridian is assigned a "false easting" of x=500000 and the equator is defined as y=0 for points in the northern hemisphere (y=10000000 for S latitudes).

III. GPSUTM: program for geodetic <--> UTM coordinates

The transformation between WGS and UTM coordinates involves calculation of the local ellipsoid radius of curvature in the meridional and transverse directions, and some series approximations which can quickly expire in terms of numerical precision if not handled with care. I have adapted an algorithm [Meade 1987] originally written for HP41 calculators (!) to Turbo Pascal, and will eventually cast it into C for embedding in our analysis procedures. This algorithm uses nested multiplications to maximize numerical precision. Program GPSUTM is designed for hand entry of individual coordinates and is accurate to 1 mm (in the sense that GPS-->UTM-->GPS works that well). The individual functions GPStoUTM and UTMtoGPS can be pulled out and used separately if you have a big file of coordinates to transform. The program reports transformed coordinates (in the case of UTM to GPS, results are given both in decimal minutes and in minutes plus decimal seconds) and the local scale factor, which gives the relationship between distance on the map and distance on the earth's surface, ie k=(map distance)/(spheroid distance).

I will put a copy of the program in the /home/dumand directory on dumand.phys.washington.edu.

IV. Data from the 12/93 DUMAND cruise

During the 12/93 deployment cruise, Ocean field rep Alex Malcolm surveyed several transponders, both the outlying navigation units and units attached to the JB and sacrificial anchor. With a few exceptions, results were provided in UTM coordinates only. Following is a table which includes geodetic coordinates from GPSUTM for all points. Since the DUMAND site is near the edge of standard Zone 4, Alex used a nonstandard central meridian of 156 deg W to provide a scale factor nearer 1.0 for our locations. In case it is ever needed, I have included another table giving conventional UTM coordinates, ie with central meridian 159W.

V. Bibliography

1. W. Torge, Geodesy, Chapter 3, de Gruyter, Berlin, 1991.
2. J. Kovalevsky, I. Mueller, B. Kolaczek, Reference Frames in Astronomy and Geophysics, Kluwer, Dordrecht, 1989.
3. P. Kissam, Surveying for Civil Engineers, Chapter 12, McGraw-Hill, New York, 1981.
4. P. W. McDonnell, Introduction to Map Projections, Dekker, New York, 1979.

VI. Tables

Table 1: Key to transponder positions

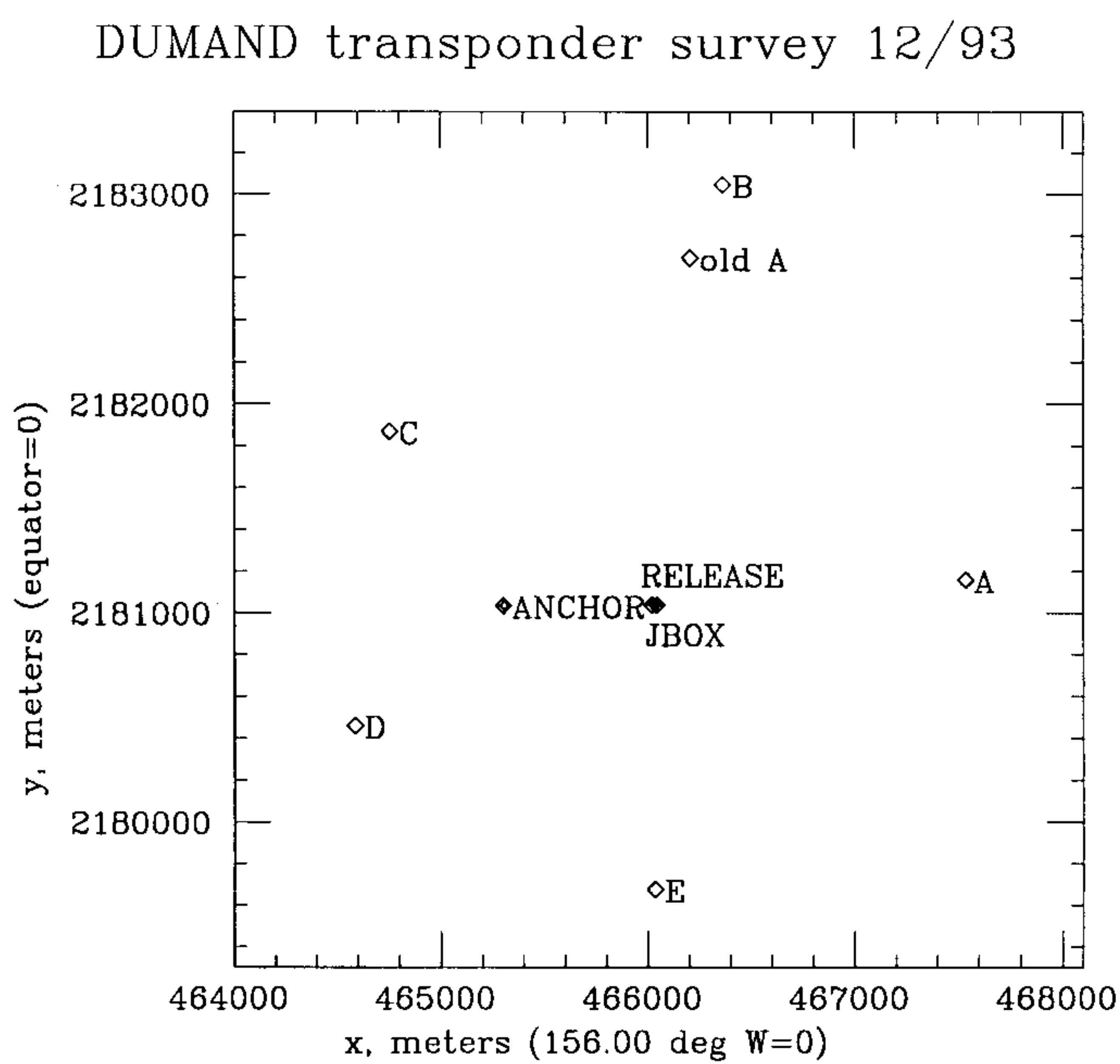
Position	Description
1	on sacrifical anchor, at time of laying operation
2	on anchor, after attempted release
3	release unit, at time of deployment
4	release unit, after attempted release
5	JBOX, at time of deployment
6	JBOX, after attempted release
7	Transponder A, 8.5 kHz
8	Transponder B, 14.4 kHz
9	Transponder C, 12 kHz
10	Transponder D, 14 kHz
11	Transponder E, 9.5 kHz
12	Transponder A' (1992 unit), 13 kHz

Table 2: 1993 acoustical survey data relative to central meridian at 156 deg W

Pos.	long		lat		E	N
1	156	19.8678	19	43.4723	465302.000	2181033.000
2	156	19.8655	19	43.4728	465306.000	2181034.000
3	156	19.4556	19	43.4747	466022.000	2181036.000
4	156	19.4550	19	43.4763	466023.000	2181039.000
5	156	19.4430	19	43.4747	466044.000	2181036.000
6	156	19.4424	19	43.4763	466045.000	2181039.000
7	156	18.5885	19	43.5429	467536.463	2181159.000
8	156	19.2608	19	44.5649	466366.000	2183046.000
9	156	20.1820	19	43.9244	464755.000	2181868.000
10	156	20.2766	19	43.1608	464587.000	2180460.000
11	156	19.4449	19	42.7373	466038.000	2179676.000
12	156	19.3500	20	44.3740	466209.542	2182694.294

Table 3: 1993 acoustical Survey data relative to standard Zone 4 meridian (159W)

Pos.	long		lat		E	N
1	156	19.8678	20	43.4723	779738.822	2183199.176
2	156	19.8655	20	43.4728	779742.828	2183200.162
3	156	19.4556	20	43.4747	780459.241	2183214.955
4	156	19.4550	20	43.4763	780460.243	2183217.925
5	156	19.4430	20	43.4747	780481.264	2183215.303
6	156	19.4424	20	43.4763	780482.267	2183218.273
7	156	18.5885	20	43.5429	781972.868	2183364.814
8	156	19.2608	20	44.5649	780767.941	2185232.671
9	156	20.1820	20	43.9244	779176.525	2184025.043
10	156	20.2766	20	43.1608	779033.301	2182612.974
11	156	19.4449	20	42.7373	780499.407	2181854.128
12	156	19.3500	21	44.3740	778825.780	2295633.449


DUMAND transponder survey 12/93
B
old A
C
RELEASE
ANCHOR
JBOX
A
D
E
2183000
2182000
2181000
2180000
y, meters (equator=0)
464000
465000
466000
467000
468000
x, meters (156.00 deg W=0)