ABSTRACT: The Universal Transverse Mercator (UTM) grid is used to reference all forest data collected in the Rocky Mountain States by the USDA Forest Service, Forest Survey Project. Display of these data with SAS/GRAPH mapping procedures requires a conversion of UTM coordinates to geographic coordinates (latitude and longitude). In this paper a SAS® DATA step is given for conversion of UTM to geographic coordinates. Also given are examples of Forest Survey maps using the SAS/GRAPH with converted UTM data.

INTRODUCTION

The Universal Transverse Mercator (UTM) grid is a map reference system for almost the entire world (USDD 1973). Only the North and South Poles are excluded. The grid consists of geographical strips or zones 6 degrees in width (fig. 1).

Map points are identified within each zone by "northing" and "easting" UTM coordinates on a metric scale (fig. 2).

UTM coordinates are planimetric and are continuous except for small breaks in the easting scale between zones. UTM coordinates are the fundamental map reference system used by the USDA Forest Service, Forest Survey Unit in the Rocky Mountain States (fig. 3).

Figure 1--UTM grid zones for the United States.

Figure 2--The UTM "northing" coordinate identifies vertical direction and the "easting" coordinate identifies horizontal direction.

The purpose of this paper is to document the conversion of UTM coordinates to geographic coordinates in a SAS DATA step and display resulting data with GMAP procedure using the ANNOTATE= Data Sets feature.
the algorithm requires UTM grid zone and northing and easting coordinates as inputs in order to give latitude and longitude as outputs. The Clark 1866 spheroid is used by the algorithm for the assumed size and shape of the earth. The algorithm, as given in this paper, is applicable to the northern hemisphere only, but easily can be modified for the southern hemisphere by adjusting the northing:

\[ Y' = 10,000,000 - Y \]

where:

\[ Y = \text{northing coordinate in southern hemisphere} \]

\[ Y' = \text{adjusted northing coordinate} \]

The mathematics of the conversion only involve algebra, but the conversion itself is based on complex geometric relationships. Further explanation is not given here but can be found in USDO (1973). Given below is a SAS DATA step including brief comments for the conversion of UTM coordinates in the northern hemisphere. Inputs for the DATA step are UTM grid zone (2-digit integer), easting (6-digit integer), and northing (7-digit integer). Also state and county (in FIPS code) are included for later merging with SAS/GRAPH map data sets.

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*CAS PROGRAM FOR CONVERSION OF UTM EASTING AND NORTHING TO LATITUDE (LATRAD) AND LONGITUDE (LONGRAD) EXPRESSED IN RADIANS

*IN RADIANS

**CALCULATATIONS FOR LATITUDE**

**FIRST CALCULATION**

\[ \text{LAT1} = \eta \times \text{TAN} \left( \Phi \right)/2.0 \]

**SECOND CALCULATION**

\[ \text{LAT2} = (2.0 - \eta) \times \text{TAN} \left( \Phi \right) - 2.0 \]

**THIRD CALCULATION**

\[ \text{LAT3} = \eta \times 16.0 \times \text{TAN} \left( \Phi \right) \]

*CALCULATING LATITUDE IN RADIANS*

\[ \text{LATRAD} = \text{LAT1} - \text{LAT2} + \text{LAT3} \]

**CALCULATIONS FOR LONGITUDE**

**FIRST CALCULATION**

\[ \text{LONG1} = \text{TAN} \left( \Phi \right)/\text{COS} \left( \Phi \right) \]

**SECOND CALCULATION**

\[ \text{LONG2} = \text{TAN} \left( \Phi \right)/\text{COS} \left( \Phi \right) + 2.0 \]

**THIRD CALCULATION**

\[ \text{LONG3} = \text{TAN} \left( \Phi \right)/\text{COS} \left( \Phi \right) - 2.0 \]

*CALCULATING LONGITUDE IN RADIANS*

\[ \text{LONGRAD} = \text{LONG1} - \text{LONG2} + \text{LONG3} \]

**CALCULATING CENTRAL MERIDIAN IN RADIANS FOR GRID ZONE ENTERED**

\[ \text{CM} = 3.165 + \text{ZONE}/100.0 \]

**CALCULATING CENTRAL MERIDIAN IN RADIANS FOR GRID ZONE ENTERED**

\[ \text{CM} = 3.165 + \text{ZONE}/100.0 \]

**CALCULATING LONGITUDE IN RADIANS**

**NOTE:** AND DIFFERENCE IF EASTING LESS THAN FALSE EASTING SUBTRACT DIFFERENCE IF EASTING GREATER THAN FALSE EASTING OF THE GRID ZONE

IF ZONE IS 1 THEN

\[ \text{LONGRAD} = \text{LONGRAD} + \text{SQRT} \left( \text{ZONE} \right) \times \text{LATUP} \times (1.0 - \text{KAK} + \text{LAT2} \times \text{KAK} / 2) \]

RUN;

SAS UTM MAPPING APPLICATIONS

Several maps were made to illustrate the usefulness of the UTM conversion algorithm when combined with the mapping features of SAS/GRAPH. The UTM data (converted to latitude and longitude) were combined and projected with the SAS map data set to assure uniform scaling. The projected UTM data were then separated from the SAS map data set. The projected UTM data were included in the GMAP procedure for final mapping using ANNOTATE= Data Sets. A similar example of this logic is given in the SAS/GRAPH User’s Guide (SAS 1985, p. 315-317).

Figure 4 illustrates 5,000-meter UTM grid points corresponding to several ownerships overlaid onto a Wyoming counties map. Five different public

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ownerships are illustrated for Wyoming. The map shows a slight problem in using special symbols with FUNCTION='LABEL' to annotate the ownerships on the map. Notice in figure 4 ownership classes below the southern Wyoming border and a small gap of no ownerships below the northern Wyoming border. There should be no ownership symbols outside the Wyoming border and National Park and National Forest ownerships should be adjacent to the northern border. These problems apparently occurred because ANNOTATE's label function centers exactly on the X and Y coordinates (SAS 1985, p. 124). Had we used ANNOTATE's symbol function (SAS 1985, p. 130) instead of the label function this problem might not have occurred. However this speculation was not tested because of a "bug" in our AOS/VS version of SAS/GRAPH (beta test version 5.03).

Also illustrated in figure 4 is the effect of a UTM zone break between zones 12 and 13 (see fig. 1) for the BLM ownership. Zone breaks are a known nuisance when selecting survey samples on a fixed UTM coordinate grid, but maps such as figure 4 will help us make a sampling correction to deal with this problem in the future.

Because the SAS code for generating figure 4 is representative of our concept for mapping UTM data, it is given below:

```
------
SAS PROGRAM FOR SUGI12 PAPER--OWNERSHIP MAP ------
GOPTIONS DEVICE=HP7475A;
LIBNAME DD1 '/D:/SASLIB/GMAP/SUGI12';
DATA PI; SET DD1.WY.PI;
O=OWNER; IF O EQ 9 OR O EQ 11 OR O EQ 12 OR O EQ 13 OR O EQ 15;
LENGTH FUNCTION $8 STYLE $8 TEXT $25 COLOR $8 POSITION $1;
FUNCTION='LABEL'; XSYS='2'; YSYS='2'; WHEN='A'; X=LONGRAD; Y=LATRAD; POSITION='5'; STYLE='SPECIAL'; COLOR='BLACK'; IF O EQ 11 THEN TEXT='K'; IF O EQ 9 OR O EQ 13 OR O EQ 15 THEN SIZE=.8;
COUNTY = -1; *** DUMMY COUNTY FOR ANNOTATE TEXT; RUN;
```
In both cases UTM data sampled on 5 000-meter grid is overlaid onto a portion of the Wyoming counties map available in SAS.

Additional resource maps for sections of Wyoming are shown in figures 5 and 6.

Figure 5--Yellowstone National Park's forest types and lakes sampled on a 5 000-meter UTM grid.

Figure 6--Wood volume for all ownerships except National Forest in the Black Hills region of northeast Wyoming sampled on a 5 000-meter UTM grid.

These maps illustrate the usefulness of a spatial display of forest survey data. In the past, Forest Survey data presentation was limited to statistical tables or charts.

Our final mapping application of UTM data involved an attempt to draw boundaries around a block of UTM data points. We selected the Wind River Indian Reservation as a test case. Identification of the boundary points (fig. 7) was straightforward. However, we had difficulty joining the points with a solid line.

Figure 7--Boundary perimeter points for Wyoming's Wind River Indian Reservation sampled on a 5 000-meter UTM grid.
In figure 8 the northeast and northwest corner boundaries double back.

Figure 8--Boundary drawn for Wyoming's Wind River Indian Reservation.

This was due to our inability to easily sort the boundary points in the correct order for certain types of concave corners. However, our SAS boundary program, given below, is a reasonable approximation for crude mapping purposes:

```
******
* SAS PROGRAM FOR IDENTIFICATION OF WIND RIVER INDIAN *
 * RESERVATION BOUNDARY POINTS FOR 5000-METER UTM GRID *
******
OPTIONS DEVICE=HP7475A;
LIBNAME D1 ':D1:SASLIB:GMAP:G112';
DATA WR 5000M; SET D1.WR 5000M; **** 5000-METER DATA FILE;
RUN;
PROC SORT DATA=WR 5000M; BY DESCENDING NORTHING EASTING;
RUN;
DATA EAST; SET WR 5000M; BY DESCENDING NORTHING;
RETAIN KNT 0;
IF LAST.NORTHING THEN DO;
   KNT=KNT+1;
   SIDE=1;
   OUTPUT EAST;
END;
RUN;
PROC SORT DATA=WR 5000M; BY DESCENDING EASTING NORTHING;
RUN;
DATA SOUTH; SET WR 5000M; BY DESCENDING EASTING;
RETAIN KNT 0;
IF FIRST.NORTHING THEN DO;
   KNT=KNT+1;
   SIDE=4;
   OUTPUT SOUTH;
END;
RUN;
PROC SORT DATA=WR 5000M; BY NORTHING EASTING;
RUN;
DATA WEST; SET WR 5000M; BY NORTHING;
RETAIN KNT 0;
IF FIRST.NORTHING THEN DO;
   KNT=KNT+1;
   SIDE=3;
   OUTPUT WEST;
END;
RUN;
DATA NORTH; SET WR 5000M; BY EASTING;
RETAIN KNT 0;
IF FIRST.EASTING THEN DO;
   KNT=KNT+1;
   SIDE=2;
   OUTPUT NORTH;
END;
RUN;
PROC SORT DATA=WIND; BY DESCENDING NORTHING EASTING;
RUN;
PROC SORT DATA=WEST; BY DESCENDING NORTHING EASTING;
RUN;
PROC SORT DATA=WEST; BY DESCENDING NORTHING EASTING;
RUN;
DATA WR_BNDRY; WHERE EAST SOUTH WEST NORTH;
BY DESCENDING NORTHING EASTING;
RUN;
PROC SORT; BY SIDE KNT;
RUN;
DATA WR_BNDRY; SET WR_BNDRY;
LENGTH FUNCTION $ 8;
RETAIN I 0;
   I=I+1;
IF I EQ 1 THEN FUNCTION="MOVE";
ELSE FUNCTION="DRAW";
KEYS='1';
SIZE=5;
WHEN='A';
LINE=1;
SIZE=0;
COLOR='BLACK';
X=LONGRAD;
Y=LATRAD;
COUNTY=-1; *** DUMMY COUNTY FOR ANNOTATE TEXT;
RUN;
DATA WR_MAP; SET D1.WR_CNTY WR_BNDRY; RUN;
PROC GPROJECT DATA=WR MAP OUT=WR_MAP);
ID COUNTY;
DATA MAP PTS WR_MAP; SET WR_MAP;
IF COUNTY EQ -1 THEN OUTPUT-WR_BNDRY;
IF COUNTY GT 0 THEN OUTPUT MAP PTS;
RUN;
PROC GMAP MAP=MAP PTS DATA=MAP PTS;
ID COUNTY;
CHORO COUNTY / COURTLINE=BLACK DISCRETE NOLEGEND
ANNOTATE=WR_BNDRY;
PATTERN1 V=E;
PATTERN2 V=E;
TITLE1 H=3;
TITLE2 H=3;
RUN;

CONCLUSION

We feel this paper has illustrated the usefulness of combining UTM referenced data with the powerful features of SAS/GRAPH to improve Forest Survey data reporting. The previous examples represent just the beginning of a new era of Forest Survey data display.
REFERENCES


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