AST1.5 Universal Transverse Mercator coordinate system

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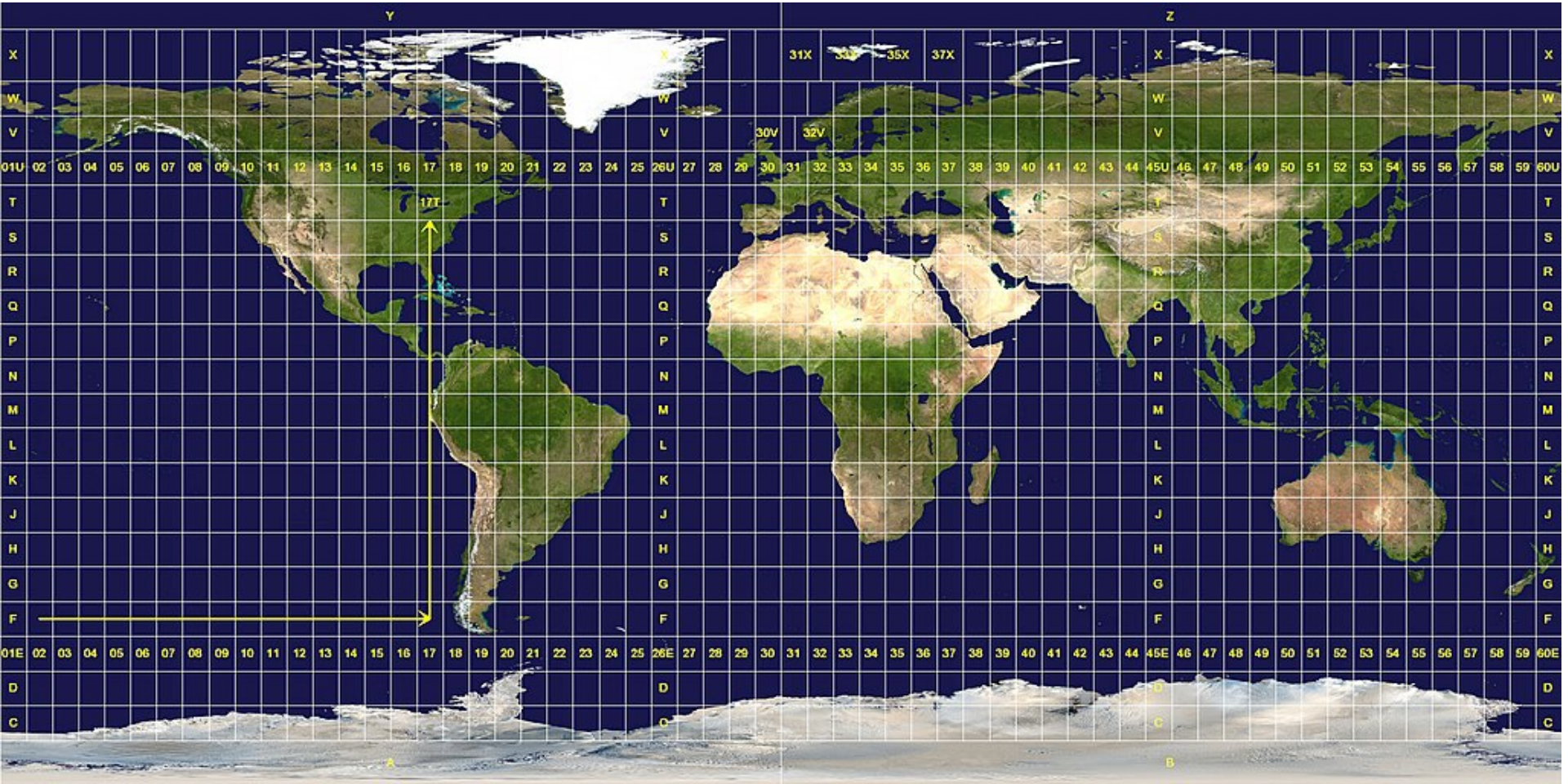
Universal Transverse Mercator coordinate system

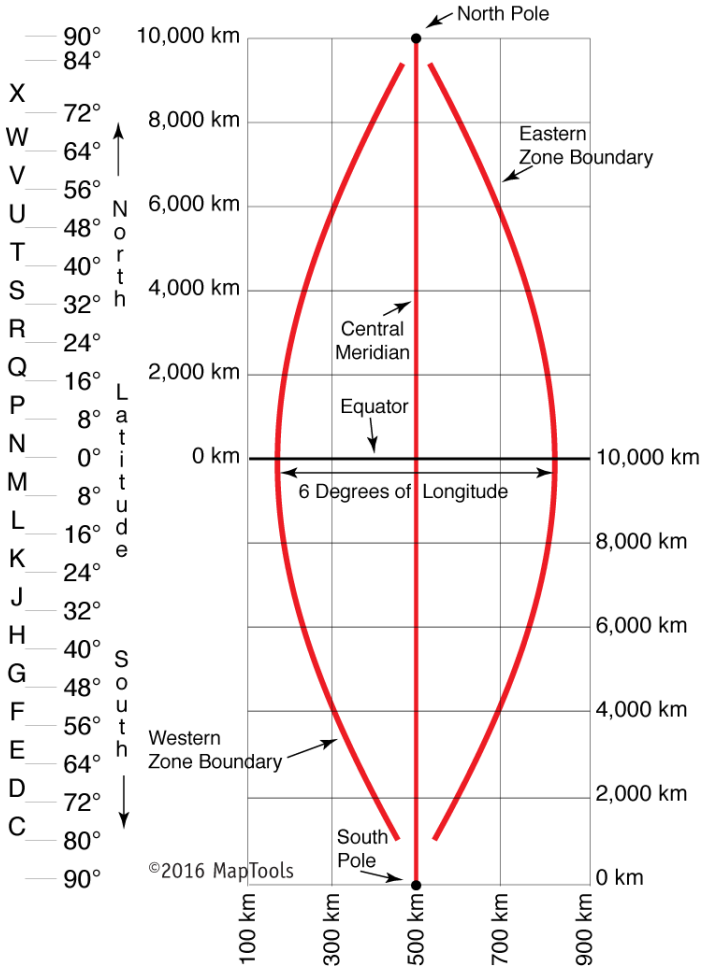
- map projection system for assigning coordinates to places on the surface of the Earth - alternative to the traditional latitude and longitude method
- Earth's surface is divided into 60 vertical zones from 80˚ south to 84˚ north
    - usually 6˚ wide
    - each has a central meridian which is used as reference meridian for projection
    - each has its own parameterization of the transverse Mercator projection - parameters vary by nation or even region



[1] Wikimedia Commons, Public domain.

UTM coordinate system

- combination of zone and latitude band defines grid zone
- UTM projection associated with the zone applied to arrive at coordinates
- projected equator then forms the X-axis, and the central meridian the Y-axis



© MapTools: https://www.maptools.com/tutorials/grid_zone_details.

Universal Transverse Mercator coordinate system

- X and Y values are given in metres
- X-value
    - X-value of the central meridian is set to 500'000 metres
    - X-value multiplied by the zone scale factor is the first coordinate - distance in metres to the east, referred to as the easting

Universal Transverse Mercator coordinate system

- Y-value
    - Southern hemisphere: equator is set by definition to 10'000'000 m
    - Northern hemisphere: equator is set by definition to 0 m
    - second coordinate is Y-value multiplied by the scale factor –distance in metres to the north, referred to as the northing
- important to specify corresponding zone number, otherwise coordinate is ambiguous
- Roman village Augusta Raurica (CH): 32T easting (X) 403767 northing (Y) 5265285

WGS84: ϕ = 47.533860˚, λ = 7.721402˚

Universal Transverse Mercator coordinate system

- conversion between UTM and WGS84 coordinates
    1. use online converter
        - https://coordinates-converter.com/en
        - http://rcn.montana.edu/resources/Converter.aspx
    2. use available software packages
        - https://search.r-project.org/CRAN/refmans/oce/html/utm2lonlat.html
    3. do it yourself
        - see formulae in downloadable slides or use our downloadable spreadsheet

Credits

Author

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Concept SEACTeach

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Design

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Conversion between UTM and WSG84 coordinate system

Source of equations: Bill Hazelton, https://www.quora.com/How-do-I-convert-UTM-into-longitude-and-latitude-without-using-software

1. constants

$a = 6'378'137$ m	semi-major axis of WGS84 ellipsoid
$e^2 = 0.0066943800$	eccentricity of WGS84 ellipsoid
$k_0 = 0.9996$	central scale factor for UTM
$\pi = 3.1415926$	ratio of a circle's circumference to its diameter

Conversion between UTM and WSG84 coordinate system

2. remove offsets

UTM coordinates: zone number, band, easting (E), northing (N)

E’ = E – 500'000 m

N’ = N (in the northern hemisphere)

N’ = N – 10'000'000 m (in the southern hemisphere)

Conversion between UTM and WSG84 coordinate system

3. calculate approximate latitude, the foot-point latitude ϕ'

intermediate steps:

$b = a * \text{sqrt}(1 - e^2)$

$n = (a - b) / (a + b)$

$G = a * (1 - n) * (1 - n^2) * (1 + 9/4 * n^2 + 225/64 * n^4) * (\pi / 180)$

G mean length of an arc of one degree of the meridian

Conversion between UTM and WSG84 coordinate system

3. calculate approximate latitude, the foot-point latitude ϕ'

$$m = N' / k_0$$

$$\sigma = (m * \pi) / (180 * G)$$

$$\phi' = \sigma + (3n/2 - 27n^3/32) * \sin 2\sigma + (21n^2/16 - 55n^4/32) * \sin 4\sigma + (151n^3/96) * \sin 6\sigma +$$

$$+ (1097n^4/512) * \sin 8\sigma$$

Conversion between UTM and WSG84 coordinate system

4. calculate geographical latitude ϕ

$$\nu' = a \,/\, \text{sqrt}\,(1 - e^2 \sin^2\phi')$$

$$\rho' = (a * (1 - e^2)) \,/\, (1 - e^2 \sin^2\phi')^{3/2}$$

$$\psi' = \nu' \,/\, \rho'$$

$$t' = \tan \phi'$$

$$x = E' \,/\, (k_0 * \nu')$$

Conversion between UTM and WSG84 coordinate system

4. calculate geographical latitude ϕ

$$\phi = \phi' - t'/(k_0\,\rho') * (x * E')/2$$

$$+ t'/(k_0\,\rho') * (x^3 * E')/24 * [-4\,\psi'^2 + 9\,\psi'\,(1 - t'^2) + 12\,t'^2]$$

$$- t'/(k_0\,\rho') * (x^5 * E')/720 * [8\,\psi'^4\,(11 - 24\,t'^2) - 12\,\psi'^3\,(21 - 71\,t'^2)$$

$$+ 15\,\psi'^2\,(15 - 98\,t'^2 + 15\,t'^4) + 180\,\psi'\,(5\,t'^2 - 3\,t'^4) + 360\,t'^4]$$

$$+ t'/(k_0\,\rho') * (x^7 * E')/40320 * (1385 + 3633\,t'^2 + 4095\,t'^4 + 1575\,t'^6)$$

$$\phi = \phi * (180 / \pi)$$

Conversion between UTM and WSG84 coordinate system

5. calculate the geographical longitude λ

$x = E' / (k_0 * \nu')$

$\omega = \sec \phi' * x - \sec \phi' * x^3/6 * (\psi' + 2\,t'^2)$

$+ \sec \phi' * x^5/120 * [-4\,\psi'^3\,(1 - 6\,t'^2) + \psi'^2\,(9 - 68\,t'^2) + 72\,\psi'\,t'^2 + 24\,t'^4]$

$- \sec \phi' * x^7/5040\,(61 + 662\,t'^2 + 1320\,t'^4 + 720\,t'^6)$

$\lambda_0 = -187 + zone * 6$ longitude of the central meridian of the UTM zone

$\lambda = \omega * (180 / \pi) + \lambda_0$