GMAT9205 Lecture 7

Transverse Mercator Projection, Lambert Conic Projection and Applications

- Features of Normal Mercator Conformal Projection
- Introduction to Transverse Mercator (TM) Projection
- Brief History of TM Projection
- Equations of TM Projection
- Universal TM Projection – UTM
- Applications of TM/UTM
- Lambert Conic Projection and Applications

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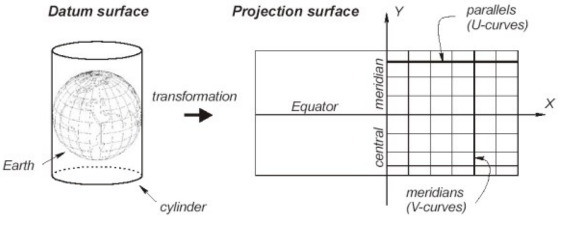
Features of Normal Mercator Projection

✓ Features of Normal Mercator Projection

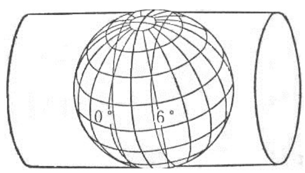
- Normal aspect **cylindrical conformal** projection
- Meridians are equally spaced straight lines
- Parallels are unequally spaced straight lines
- Scale is constant along the Equator
- Poles are at infinity; great distortion of area in polar regions
- Low scale error in a small latitude band close to the Equator
- Larger scale errors in higher latitude regions

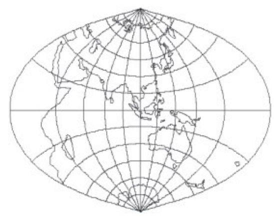


Introduction to Transverse Mercator (TM) Projection

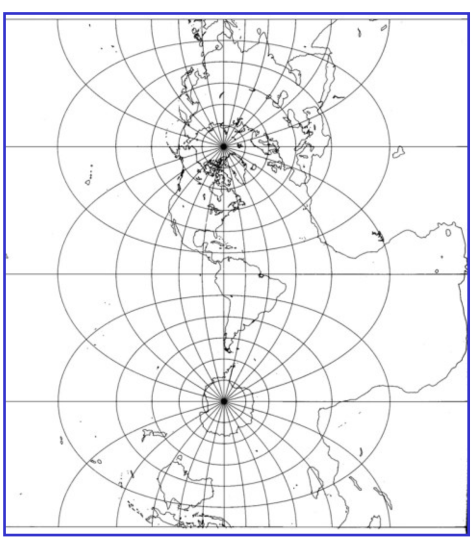
✓ Features of Transverse Mercator Projection

- Transverse **cylindrical conformal** projection
- Central meridian and Equator are straight lines
- Other meridians and parallels are complex curves
- Scale is constant along central meridian
- Larger scale errors as the longitude difference from the central meridian increases





Introduction to Transverse Mercator (TM) Projection



While the regular Mercator has constant scale along the Equator, the Transverse Mercator has constant scale along any chosen central meridian. This projection is conformal and is often used to show regions with north-south extent

Brief History of Transverse Mercator Projection

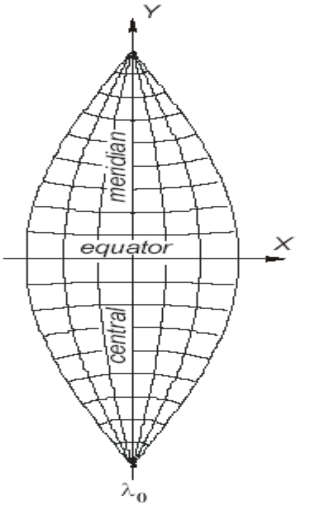
- ✓ The TM in its spherical form was invented in 1772 by **Johann Heinrich Lambert.**
- ✓ **Carl Friedrich Gauss** develped the ellipsoidal form in 1822
- ✓ **Krüger** published studies in 1912 and 1919 providing formulas suitable for calculation relative to the ellipsoid
- ✓ In Europe the projection is sometimes called **Gauss conformal** or **Gauss-Krüger**
- ✓ The ***Transverse Mercator*** , now common usage, was first applied by the French map projection compiler **Germain**
- ✓ Until recently, the TM projection was not precisely applied to the ellipsoid for the entire Earth.
- ✓ In 1945, E.H. **Thompson** presented exact or closed formulas permitting calculation of coordinates for the full ellipsoid

Johann Heinrich Lambert (1728-1777)

Inventor of the TM, the Conformal Conic, the Azimuthal Equal-Area, and other important projections,

Introduction to Transverse Mercator (TM) Projection

- Because the map is **conformal** shapes and angles within any small area are essentially true.
- All distances, directions, shapes, and areas are reasonably accurate within 15° of the central meridian.
- **Distortion** of distances, directions, and size of areas increases rapidly outside the 15° band.



Equations for TM Map Projection

- see R.E. Deakin (2004) for all the notations

$$X = k_0 \left\{ \nu\omega\cos\phi + \nu\frac{\omega^3}{6}\cos^3\phi\left(\psi - t^2\right) + \nu\frac{\omega^5}{120}\cos^5\phi\left[4\psi^3\left(1-6t^2\right) + \psi^2\left(1+8t^2\right) - \psi\left(2t^2\right) + t^4\right] + \nu\frac{\omega^7}{5040}\cos^7\phi\left(61 - 479t^2 + 179t^4 - t^6\right) \right\}$$

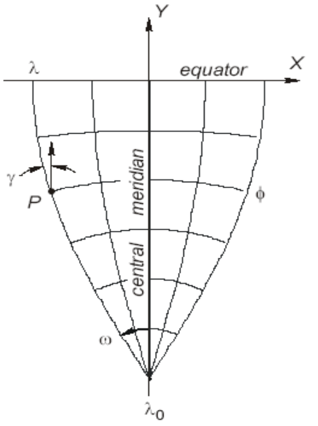
$$Y = k_0 \left\{ m + \nu\sin\phi\frac{\omega^2}{2}\cos\phi + \nu\sin\phi\frac{\omega^4}{24}\cos^3\phi\left(4\psi^2 + \psi - t^2\right) + \nu\sin\phi\frac{\omega^6}{720}\cos^5\phi\begin{bmatrix}8\psi^4\left(11-24t^2\right) - 28\psi^3\left(1-6t^2\right) \\ +\psi^2\left(1-32t^2\right) - \psi\left(2t^2\right) + t^4\end{bmatrix} + \nu\sin\phi\frac{\omega^8}{40320}\cos^7\phi\left(1385 - 3111t^2 + 543t^4 - t^6\right) \right\}$$

Grid Convergence γ on a TM projection

Grid convergence γ (gamma) at a point P is the angle between *True North*, the direction of the projected meridian through P, and *Grid North*, the direction of a line through P that is parallel with the central meridian.

Grid convergence is defined by the differential relationship

$$\tan\gamma = -\frac{dX}{dY}$$



$$\gamma = \omega\sin\phi \left\{ 1 + \frac{\omega^2\cos^2\phi}{3}\left(2\psi^2 - \psi\right) + \frac{\omega^4\cos^4\phi}{15}\begin{bmatrix}\psi^4\left(11-24t^2\right) - \psi^3\left(11-36t^2\right) \\ +2\psi^2\left(1-7t^2\right) + \psi t^2\end{bmatrix} + \frac{\omega^6\cos^6\phi}{315}\left(17 - 26t^2 + 2t^4\right) \right\}$$

Why do we need to know the Point Scale Factor?

- **Point Scale Factor is a measure of (differential) distance distortion for a specific map projection at a point.**
- **For a conformal map projection, the point scale factor is independent of the azimuth – this is the reason why the shapes/angles are true.**
- **For a TM projection, the point scale factors on the central meridian are equal (To a defined constant value – UTM 0.9996)**

$$k^2 = \frac{dS^2}{ds^2} = \frac{E\,d\phi^2 + G\,d\lambda^2}{e\,d\phi^2 + g\,d\lambda^2} = \frac{(dX)^2 + (dY)^2}{\rho^2\,d\phi^2 + \nu^2\cos^2\phi\,d\lambda^2}$$

$$k = k_0 \left\{ \begin{array}{l} 1 + \dfrac{\omega^2\cos^2\phi}{2}(\psi) \\ + \dfrac{\omega^4\cos^4\phi}{24}\left\{4\psi^3\left(1-6t^2\right) + \psi^2\left(1+24t^2\right) - 4\psi\left(t^2\right)\right\} \\ + \dfrac{\omega^6\cos^6\phi}{720}\left(61 - 148t^2 + 16t^4\right) \end{array} \right\}$$

Usage of The Transverse Mercator Projection

U.S. Geological Survey (USGS)

: chose **the spherical form of the TM** for a base map of North America at a scale of 1:5,000,000 (in 1979) to place **the Bipolar Oblique Conic Conformal** projection previously used for tectonic and other geologic maps

- **Scale Factor:** 0.926 along the central meridian (longitude 100°W)
- **Radius of the Earth:** 6,371,204 m
- Two straight lines of true design scale 2,343 km on each side of the central meridian

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