Lunar Plane Coordinate System

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Typical Coordinate Systems

In the case of the earth, a typical Coordinate System is following three coordinate systems.

(1) 3-Dimensional Coordinate System

The Cartesian Coordinate System with the direction of the north pole of rotation axis as the Z axis.

(2) Latitude and Longitude

Latitude and Longitude on the ellipsoid.

(3) Plane Coordinate System

The coordinate system of projection for the spherical surface into plane.

Lunar 3-D Coodinate System

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Report of the IAU Working Group on Cartographic Coordinates and Rotational Elements: 2015

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The 3 Dimensional Coordinate System,
Including the moon,
have already been determined
by
the International Astronomical Union (IAU).

Lunar 3-D Coordinate System

Table 1 Recommended values for the direction of the north pole of rotation and the prime meridian of the Sun and planets

α_0, δ_0	Are ICRF equatorial coordinates at epoch J2000.0
	Approximate coordinates of the north pole of the invariable plane are $\alpha_0 = 273^\circ.85$,
$T =$	Interval in Julian centuries (36,525 days) from the standard epoch
$d =$	Interval in days from the standard epoch
The standard epoch is JD 2451545.0, i.e., 2000 January 1 12 h TDB	

Sun
$$\alpha_0 = 286^\circ.13$$
$$\delta_0 = 63^\circ.87$$
$$W = 84^\circ.176 + 14^\circ.1844000d^{(a)}$$

Mercury
$$\alpha_0 = 281.0103 - 0.0328\,T$$
$$\delta_0 = 61.4155 - 0.0049\,T$$
$$W = 329.5988 \pm 0.0037 + 6.1385108d + 0^\circ.01067257 \sin M1 - 0^\circ.00112309 \sin M2 - 0^\circ.00011040 \sin M3 - 0^\circ.00002539 \sin M4 - 0^\circ.00000571 \sin M5$$

where
$$M1 = 174^\circ.7910857 + 4^\circ.092335d$$
$$M2 = 349^\circ.5821714 + 8^\circ.184670d$$
$$M3 = 164^\circ.3732571 + 12^\circ.277005d$$
$$M4 = 339^\circ.1643429 + 16^\circ.369340d$$
$$M5 = 153^\circ.9554286 + 20^\circ.461675d^{(b)}$$

Venus
$$\alpha_0 = 272.76$$
$$\delta_0 = 67.16$$
$$W = 160.20 - 1.4813688d^{(c)}$$

Mars
$$\alpha_0 = 317.269202 - 0.10927547T + 0.000068 \sin(198.991226 + 19139.4819985T) + 0.000238 \sin(226.292679 + 38280.8511281T) + 0.000052 \sin(249.663391 + 57420.7251593T) + 0.000009 \sin(266.183510 + 76560.6367950T) + 0.419057 \sin(79.398797 + 0.5042615T)$$
$$\delta_0 = 54.432516 - 0.05827105T + 0.000051 \cos(122.433576 + 19139.9407476T) + 0.000141 \cos(43.058401 + 38280.8753272T) + 0.000031 \cos(57.663379 + 57420.7517205T) + 0.000005 \cos(79.476401 + 76560.6495004T)$$

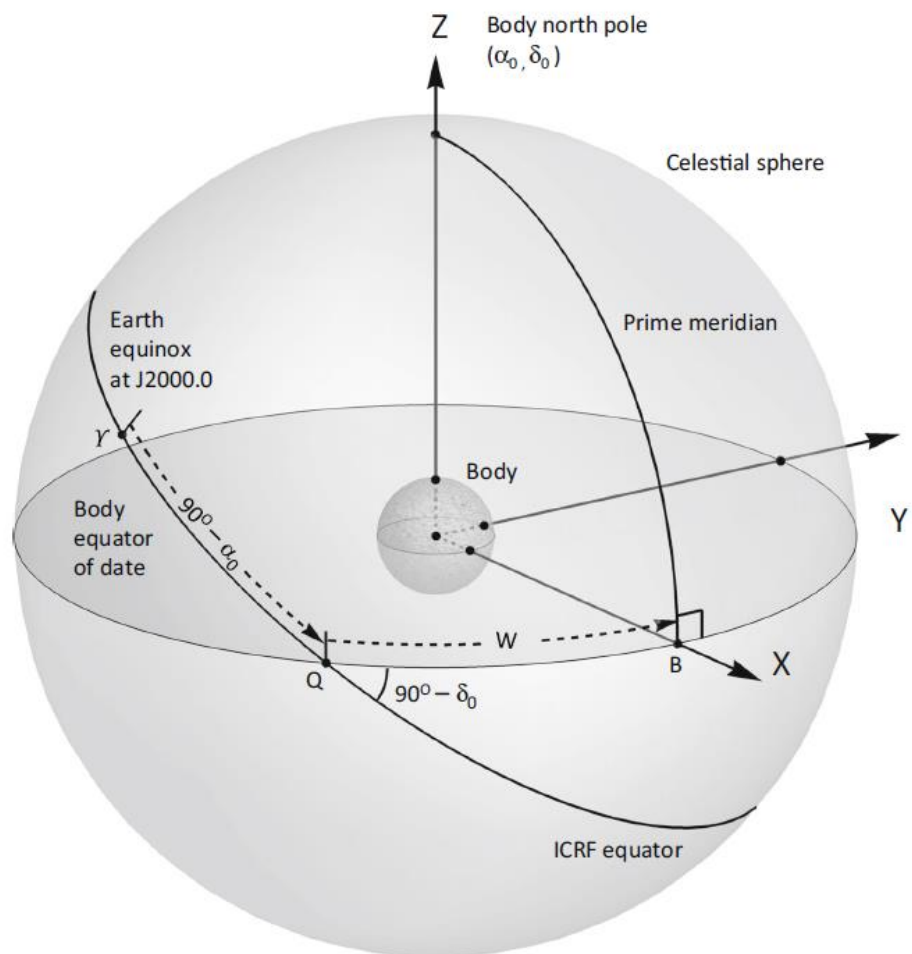


Fig. 1 Reference system used to define orientation of the planets and their satellites. For $\dot{W}(t) > 0$, body rotation is prograde (e.g., Mercury, Jupiter). For $\dot{W}(t) < 0$, body rotation is retrograde (e.g., Venus, Uranus)

Lunar 3-D Coordinate System

3 The lunar coordinate system

The recommended coordinate system for the Moon is the mean Earth/polar axis (ME) system. There is an offset between this system and the principal axis (PA) system, sometimes called the axis of figure system (Davies and Colvin 2000).

The ME system is recommended because nearly all cartographic products have been aligned to it (ibid.). The offset between these coordinate systems of a point on the lunar surface is approximately 860 meters. Previous reports included the rotation and pole position for the ME system using closed formulae in Table 2. We are not continuing to provide those formulae as they are *only* accurate to approximately 150 m (e.g., Konopliv et al. 2001, Fig. 3). For high accuracy work (e.g., spacecraft operations, high-resolution mapping, and gravity field determination), it is recommended that a lunar ephemeris be used to obtain the libration angles for the Moon, from which the pole position and rotation can be derived.

The 3 Dimensional Coordinate System, for the Moon and Earth polar axis (ME) system is recommended.

Lunar 3-D Coordinate System

Table 3 Recommended rotation values for the direction of the positive pole of rotation and the prime meridian of selected dwarf planets, minor planets, their satellites, and comet

d is the interval in days from the standard epoch, i.e., J2000.0 = JD 2451545.0, i.e., 2000 January 1 12 h TDB or from the given epoch for the listed comets. α_0, δ_0, W, and $\dot{W}$ are as defined in the text

(1) Ceres	$\alpha_0 = 291^\circ.418 \pm 0^\circ.03$
	$\delta_0 =$ (
	$W =$
(2) Pallas	$\alpha_0 =$
	$\delta_0 =$ -
	$W =$
(4) Vesta	$\alpha_0 =$
	$\delta_0 =$
	$W =$
(21) Lutetia	$\alpha_0 =$
	$\delta_0 =$
	$W =$
(52) Europa	$\alpha_0 =$
	$\delta_0 =$
	$W =$
(243) Ida	$\alpha_0 =$
	$\delta_0 =$ -
	$W = 274^\circ.05 + 1864^\circ.6280070d^{(f)}$

Parameter for
dwarf planets,
minor planets,
their satellites,
and
Comet
have already been determined.

Lunar Latitude and Longitude

A Standardized
Lunar Coordinate System for the
Lunar Reconnaissance Orbiter

The latitude and longitude of the lunar coordinate system has been determined by NASA

Previous Versions:
Version 1: 2006 August 23
Version 2: 2007 January 24
Version 3: 2008 January 30

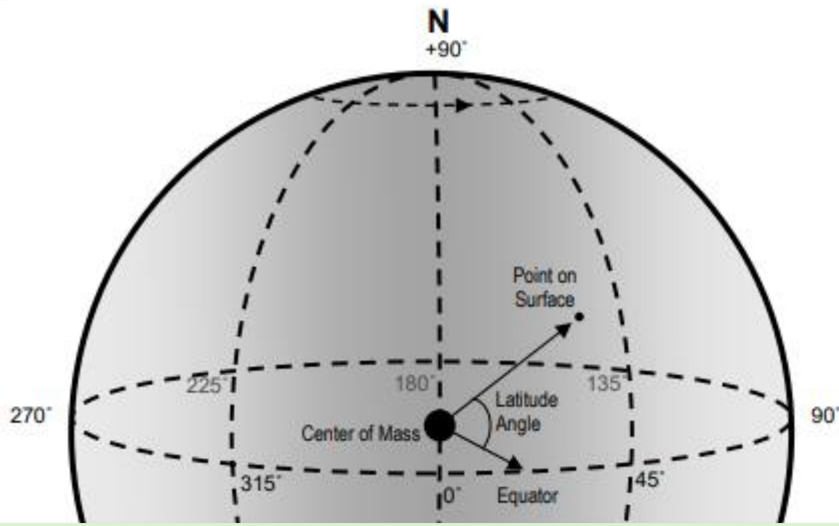
National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Lunar Latitude and Longitude

operations planning, observational targeting, geographic identification of lunar landforms, and inter-mission communications.

The prime meridian (longitude 0) is the center visible from Earth.



The latitude and longitude of the lunar coordinate system has been determined by NASA

Figure 1. Planetocentric coordinates are expressed as right-handed coordinates with the origin at the center of mass of the body.

Plane Coordinate System

The 3 Dimensional and Latitude and Longitude coordinate system has already been determined, but there is no Planar Coordinate System.

↓

The 3 D coordinate system is difficult to use on the lunar surface, and the latitude and longitude coordinate system is difficult to use because its units are angles

↓

It is more efficient to carry out building layout and infrastructure maintenance on the moon in metric

Necessity of the plane coordinate system

When developing infrastructure on the moon,
it is planned and designed on a flat surface using CAD

↓

In cases such as complex plant construction,
high layout accuracy is required.

↓

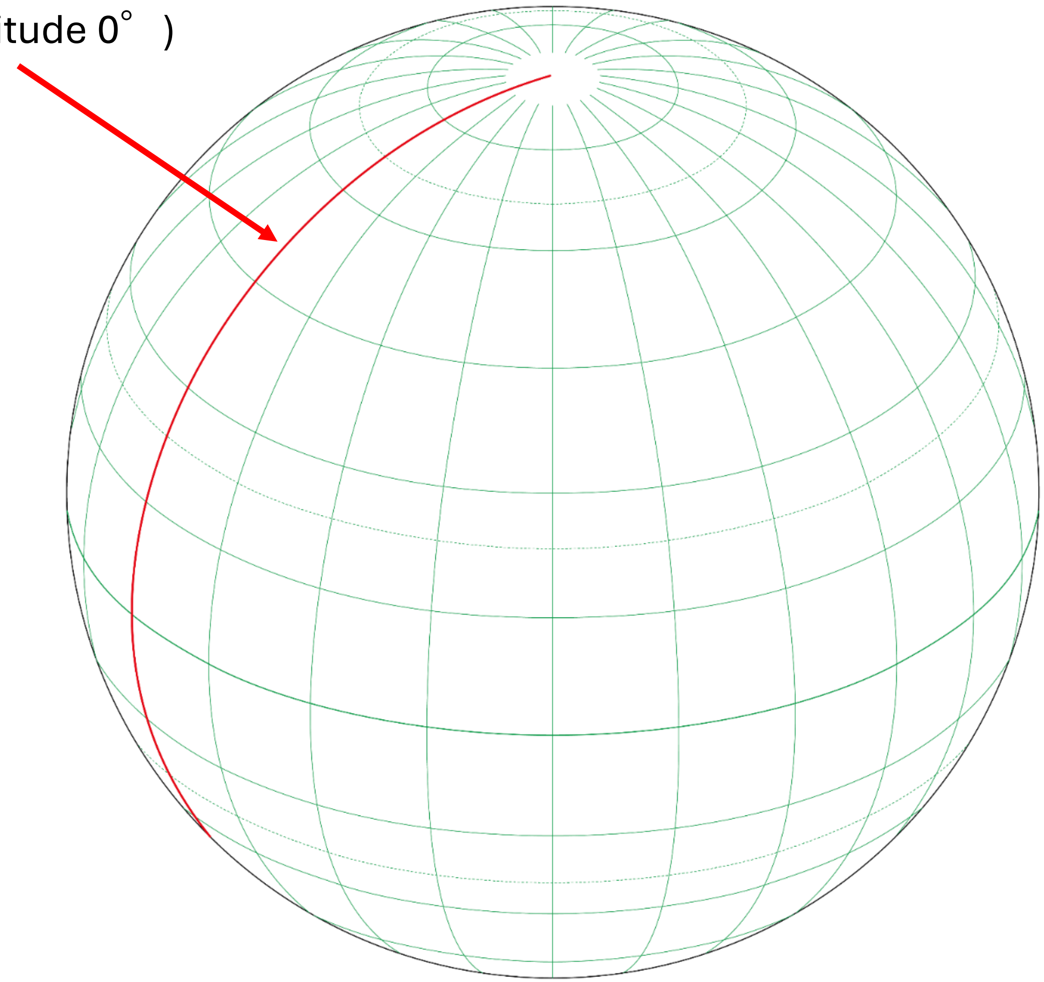
Construction is difficult in latitude and longitude,
therefore, construction is required in metric

↓

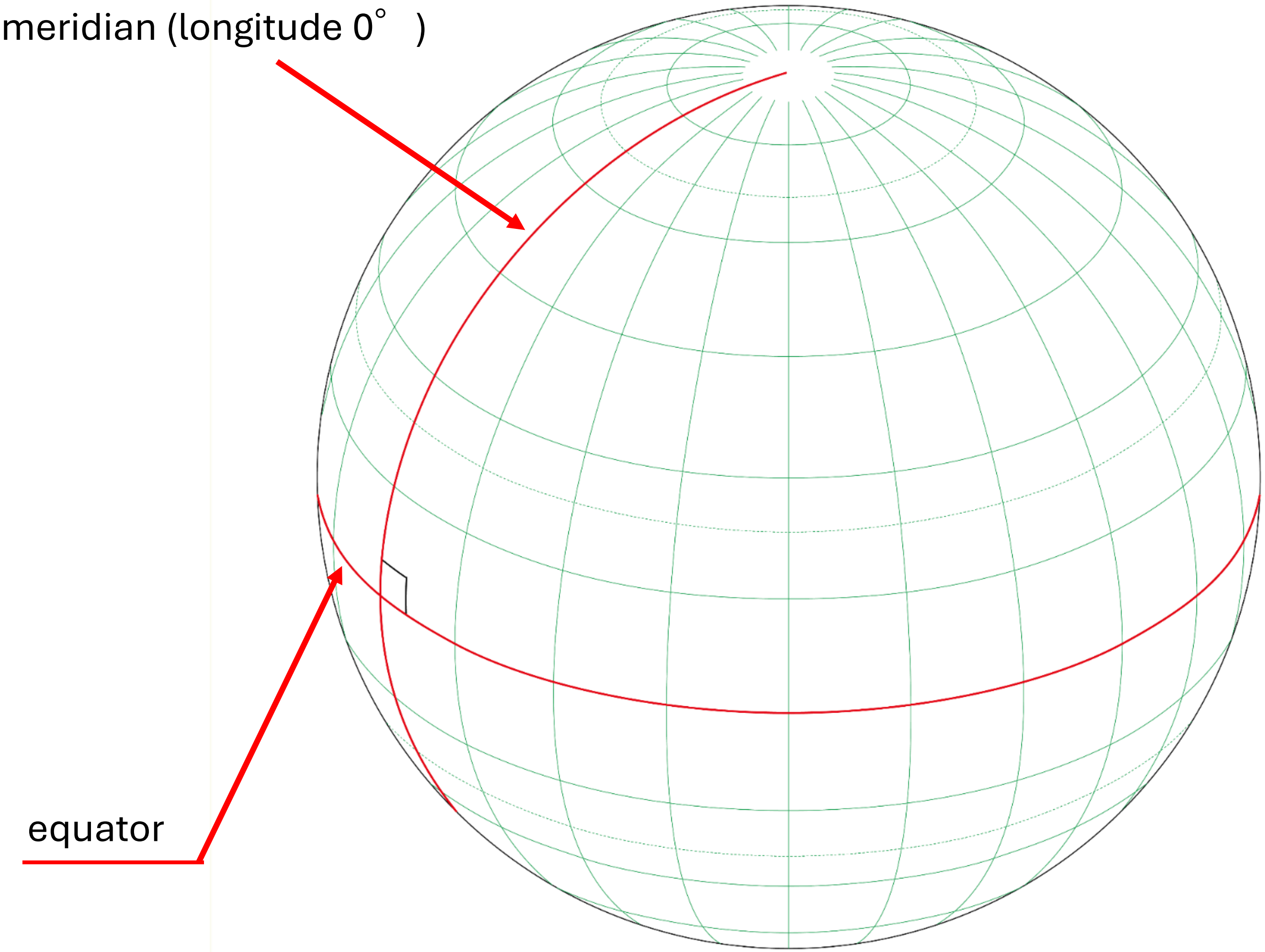
Planar coordinate system needs to be prepared

Problems when projecting a spherical surface onto a plane

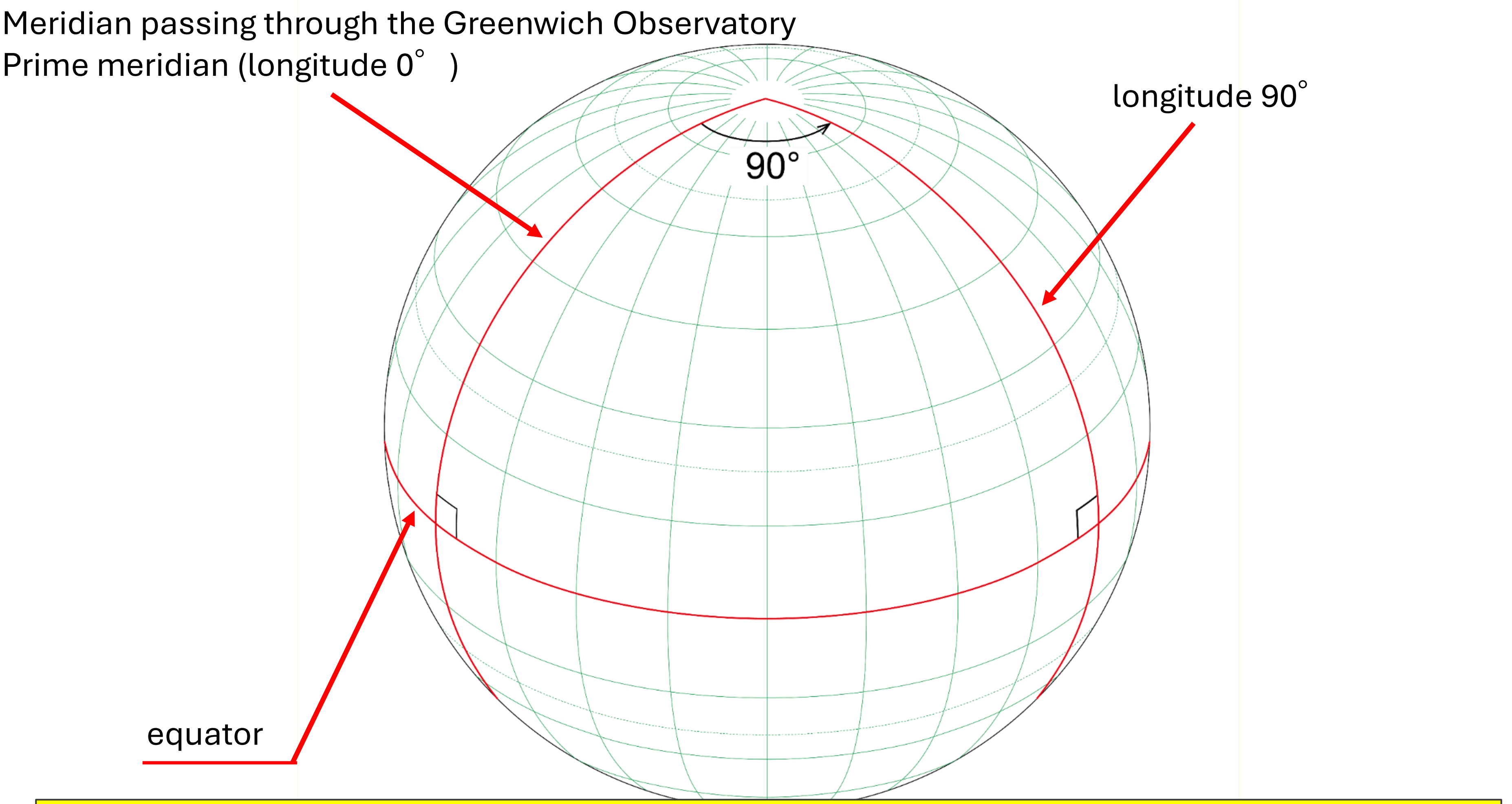
Meridian passing through the Greenwich Observatory
Prime meridian (longitude 0°)



Problems when projecting a spherical surface onto a plane



Problems when projecting a spherical surface onto a plane



sum of interior angles of this triangle = 270° (≠180°)

Problems when projecting a spherical surface onto a plane

Moon is an ellipsoid

↓

The shapes on the lunar surface are on a curved surface

↓

When a figure on a spherical surface is projected onto the plane,
Angle
Distance
Area
cannot be projected correctly.

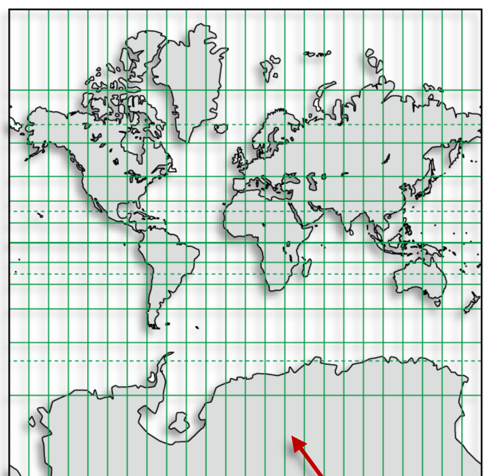
↓

Euclidean geometry does not hold.

Mercator’s Projection & Transversal Mercator’s Projection

The UTM coordinate system is commonly used as a globally used coordinate system.

(UTM : Universal Transversal Mercator)

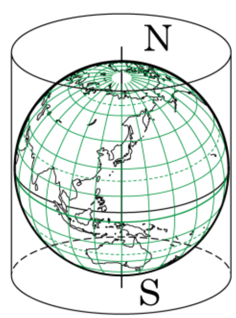


projection_10.ai

Mercator’ s projection メルカトル図法

Antarctica

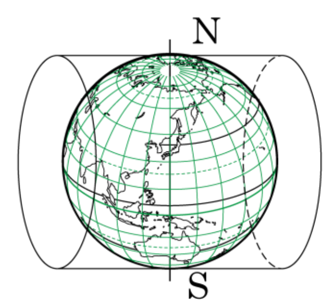
The Mercator’s projection distorts the polar regions.



Mercator’ s Projection
(Cylindrical)

projection_11.ai

Next sheet

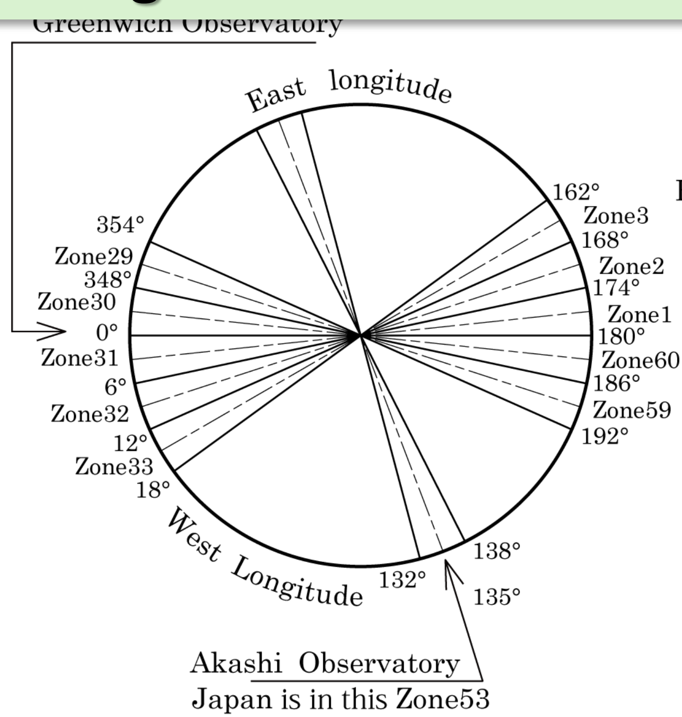


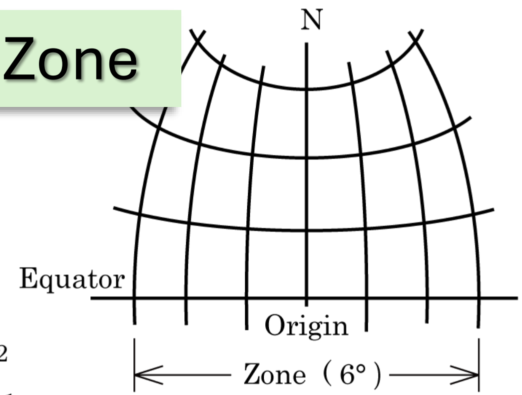
Transversal Mercator ‘s Projection

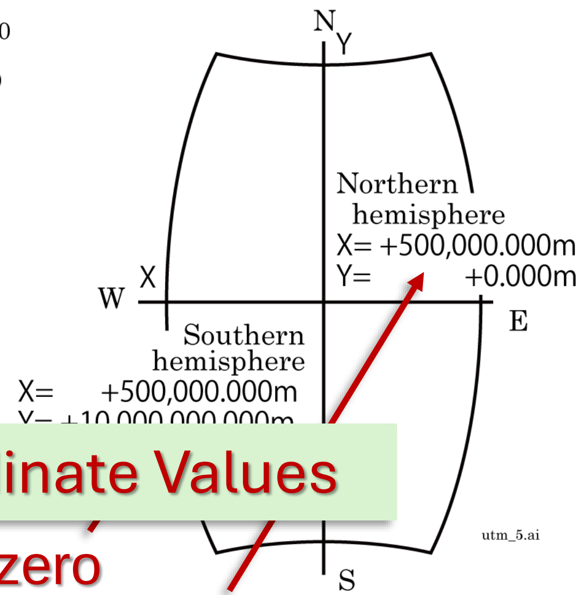
Transversal Mercator Projection

In the case of Earth :

Reconsidering the width of each Zone







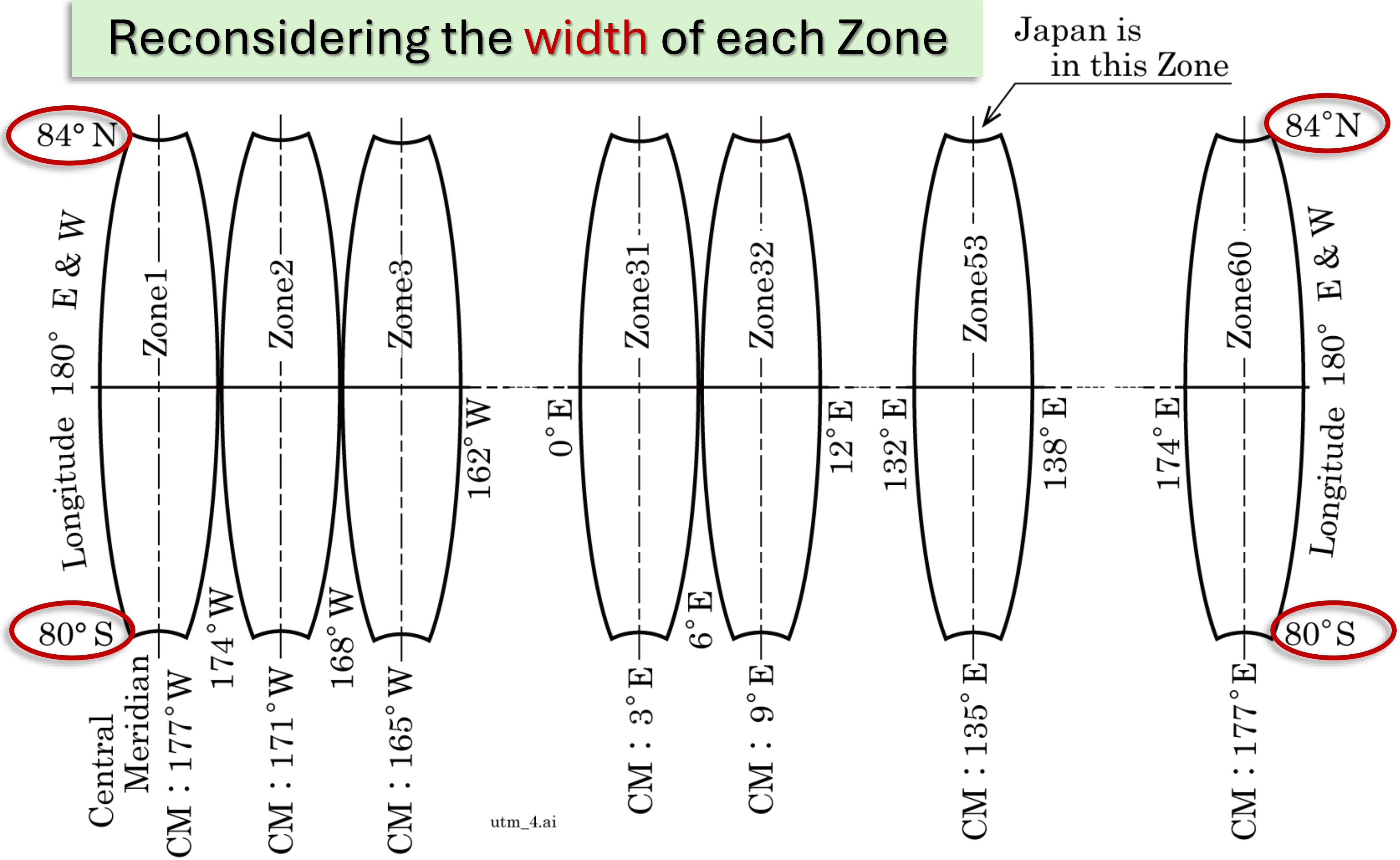
Reconsidering the Origin Coordinate Values

The origin coordinates are not zero and are biased to avoid negative coordinates.

Transversal Mercator Projection

In the case of Earth :

Reconsidering the width of each Zone



Universal Transversal Mercator on the Earth

In the case of Earth :

Earth's major axis : a ,   flattening facor : f , central meridian : λ_0

Latitude and Longitude (φ, λ) is calculated (x, y) by the following formula.

$$x = x_0 + k_0 A \left(\eta' + \sum^{3} \alpha_j \cos(2j\xi') \sin(2j\eta') \right)$$

Reconsidering

the parameters of the formula for converting

latitude and longitude to plane coordinates.

$$y = y_0 + k_0 A \left(\eta' + \sum_{j=1} \alpha_j \sin(2j\xi') \cosh(2j\eta') \right)$$

$x_0 = 500$ [km] , $y_0 = 10,000$ [km]

Universal Transversal Mercator on the Earth

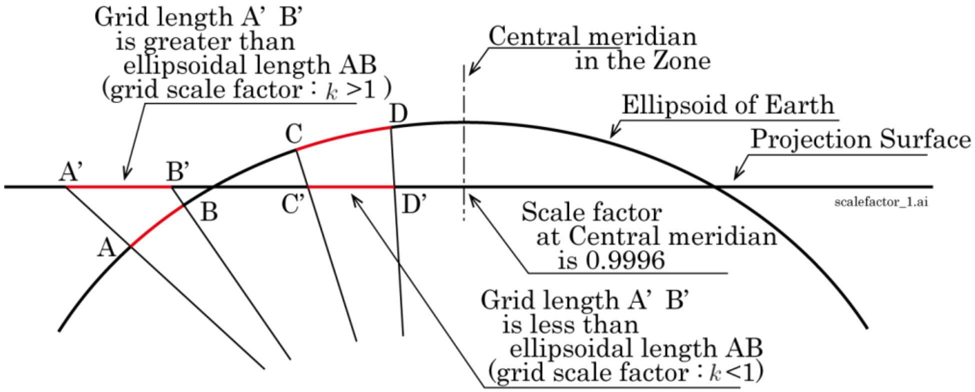
In the case of Earth :

Scale factor :

Scale Factor at Central meridian : $k_0 = 0.9996$

Grid Scale Factor : k

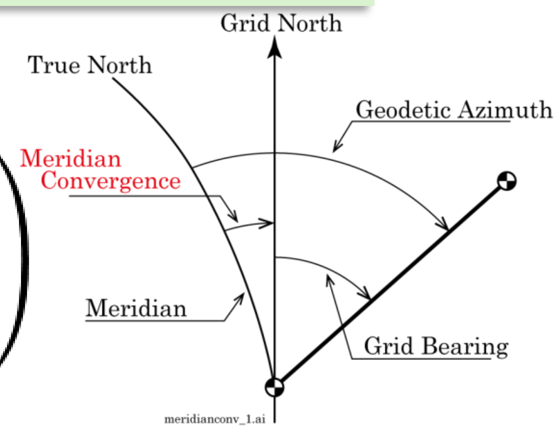
$A'B' = k \cdot AB$



Reconsidering the parameters of the formula for computing the Scale factor and the Meridian convergence.

Meridian convergence :

$$\gamma = \tan^{-1}\left(\frac{\tau\sqrt{1+t^2} + \sigma t \tan(\lambda - \lambda_0)}{\sigma\sqrt{1+t^2} - \tau t \tan(\lambda - \lambda_0)}\right)$$



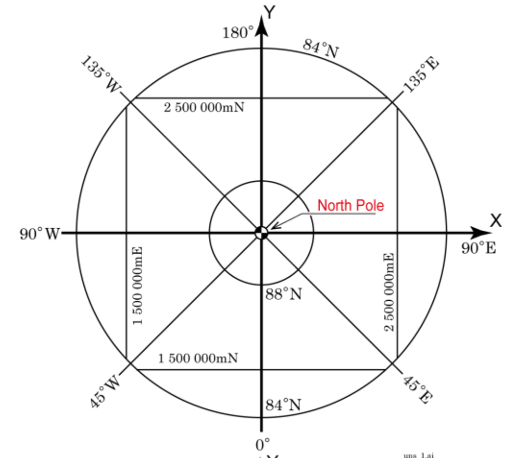
UPS Coordinate System

Universal Polar Stereographic (UPS) projection is a map projection method for the area around the North Pole and the South Pole, and is a plane coordinate system.

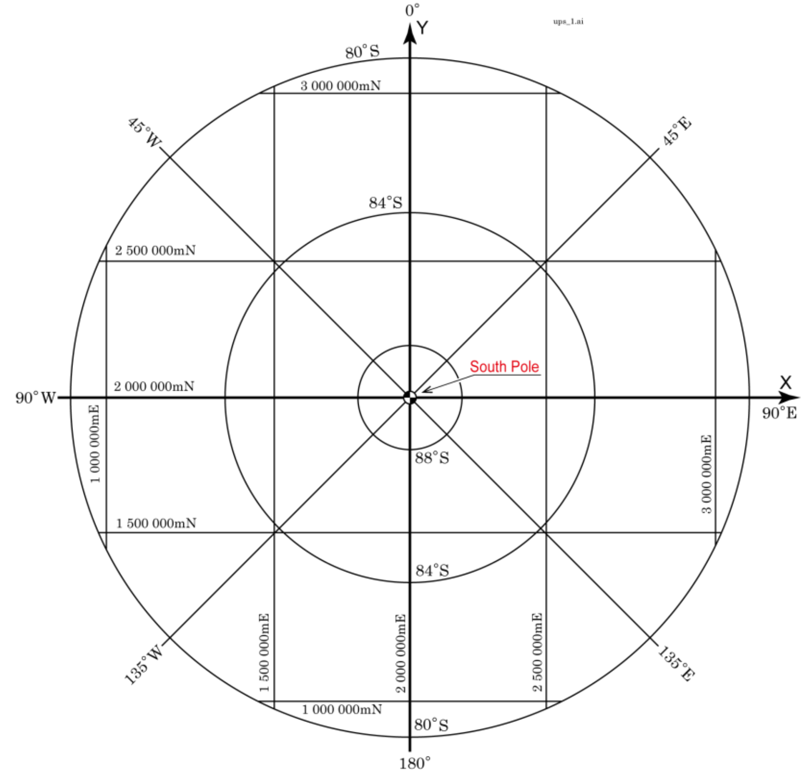
Combined with the Universal Transverse Mercator (UTM) projection, it covers the entire earth surface.

UPS Coordinate System

Targets areas north of 84°N and south of 80°S.

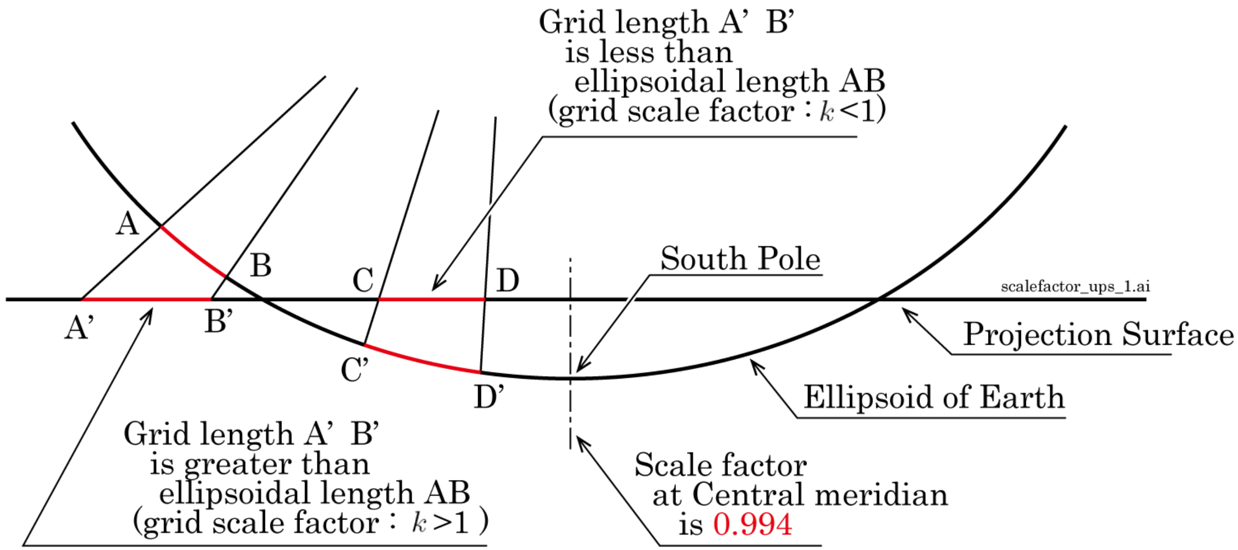


In order to connect with the target area of the UTM projection, it is assumed that it will extend outward by 0.5°.



UPS Coordinate System

Scale factor :

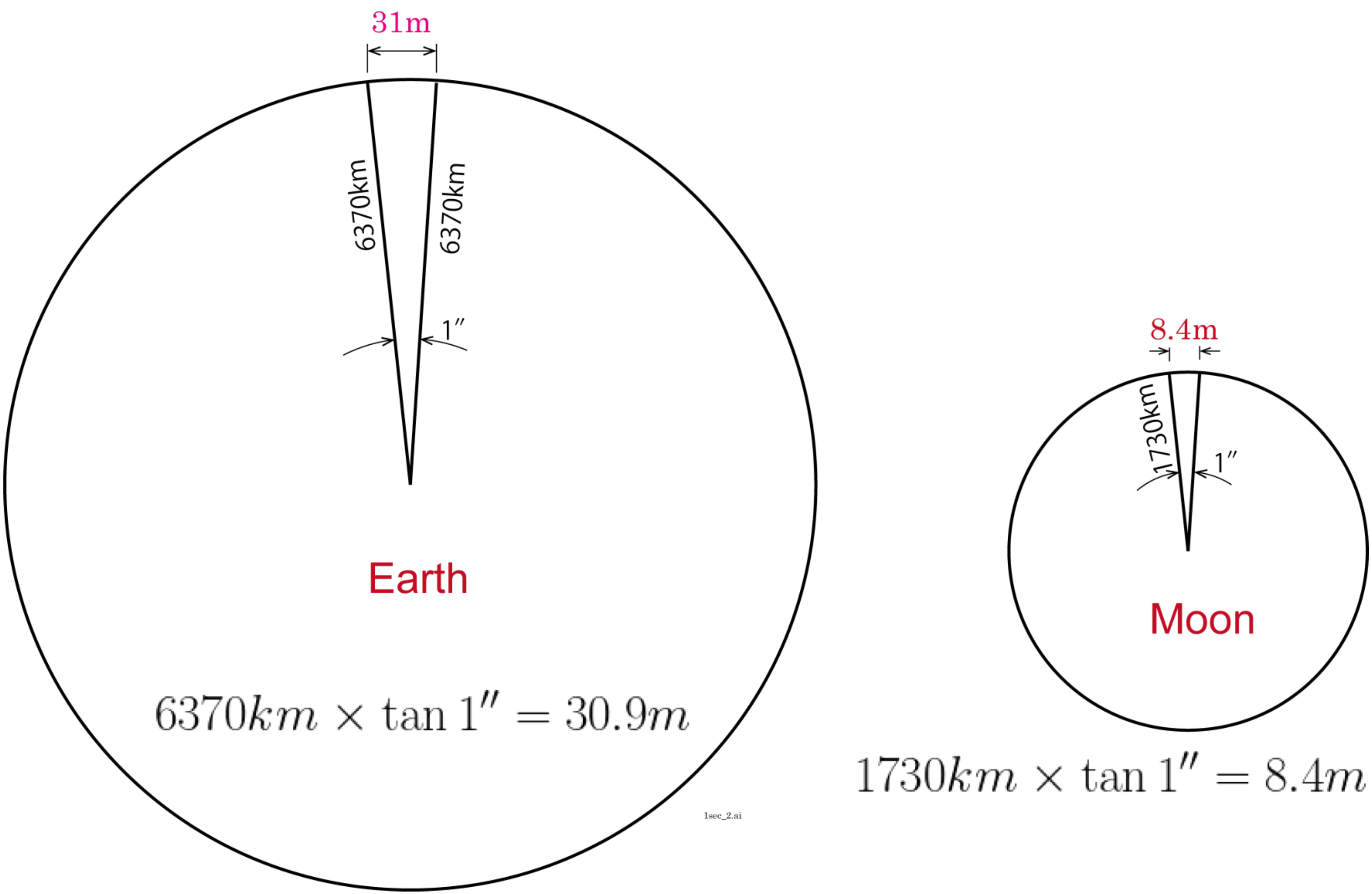


On Earth, the polar regions are rarely used, so the accuracy of the scale factor is not important.

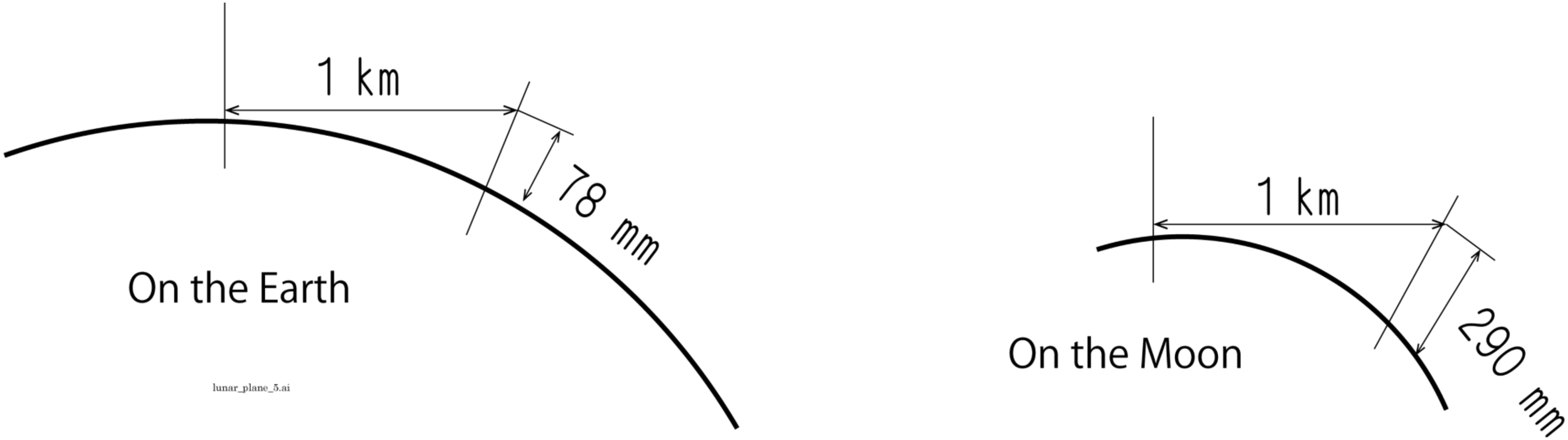
However, the moon is planned to be used in the south polar region.

Research optimal coefficients and parameters.

Issue of Planar coordinate system on the moon



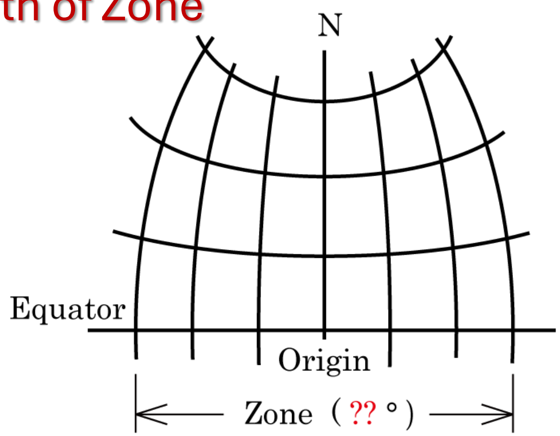
Issue of Planar coordinate system on the moon



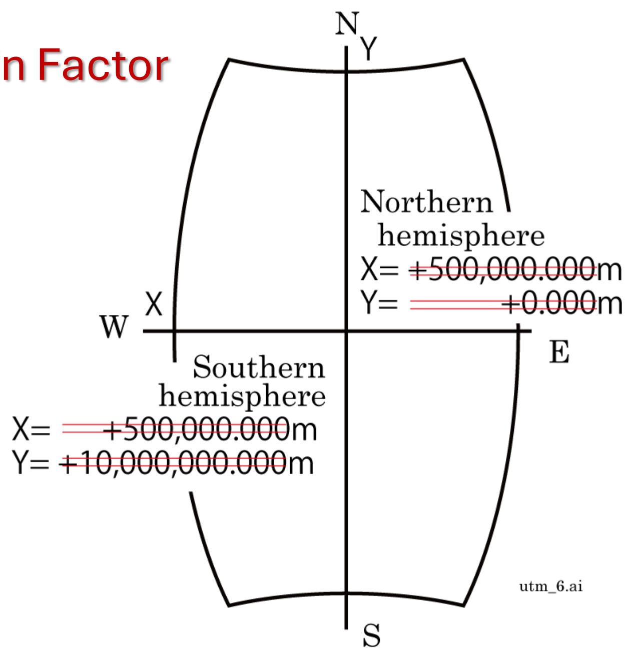
The moon's radius is about 1/4 of the Earth's radius

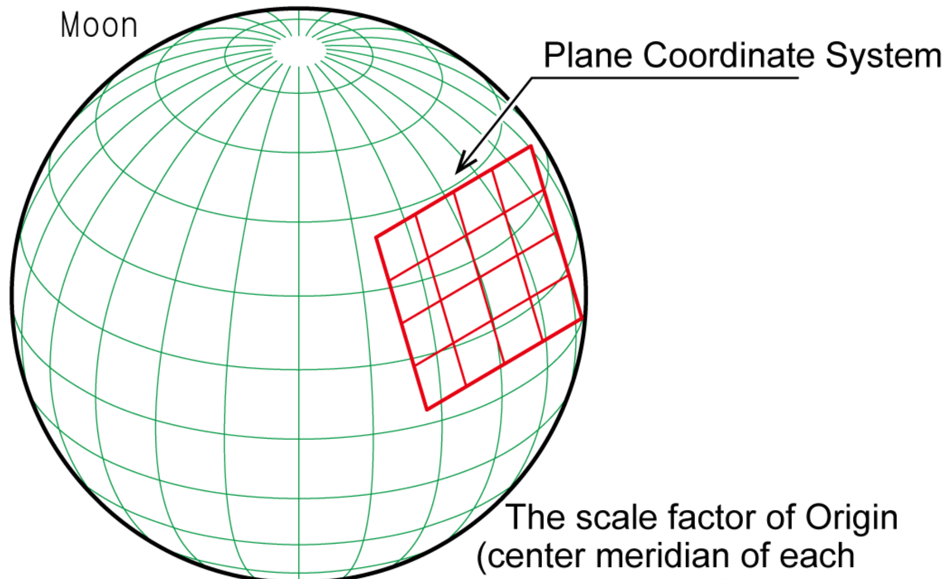
Issue of Planar coordinate system on the moon

Width of Zone



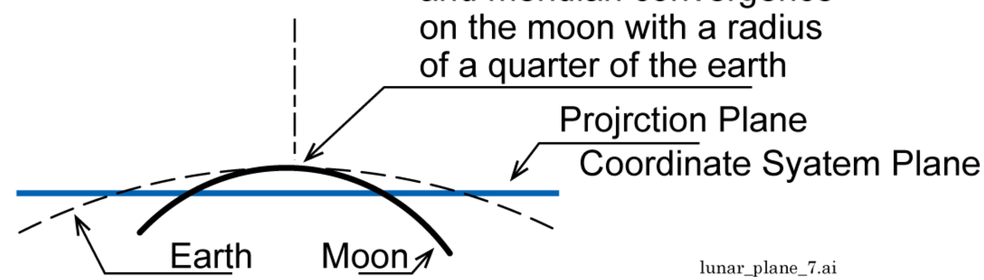
Origin Factor





The scale factor of Origin (center meridian of each coordinate system) on the Earth's UTM coordinate system is 0.9996.

Researching the optimal scale factor and meridian convergence on the moon with a radius of a quarter of the earth



New Coordinate System

If the parameters of both UTM & UPS coordinate systems are found to be inappropriate, considering a new optimal plane coordinate system.

More detailed proposals
will be made up
at the next meeting

Thank you for your attention