Automotive Sensor

GNSS

"GPS"

(Global Navigation Satellite System)

Automotive Intelligence Lab.

Contents

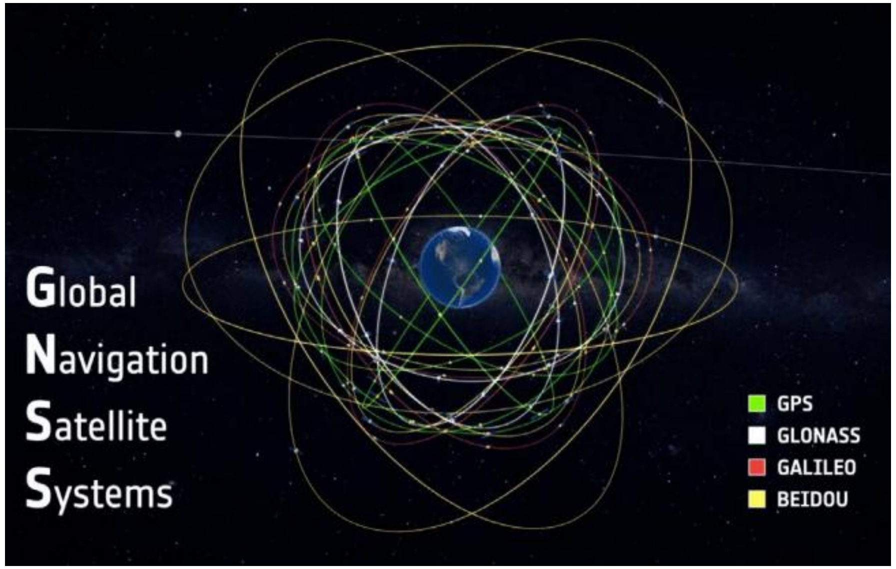
What is GNSS?

GNSS Overview

- **Global Navigation Satellite System (GNSS)**
  - a system that uses satellites to provide geo-spatial positioning.
  - It allows receivers to determine their location using time signals transmitted along a line of sight by radio from satellites.

- **GNSS (Global Navigation Satellite Systems) started with the launch of the U.S Department of Defense Global Positioning System (GPS) in the late 1970's.**

- **GNSS systems currently include**
  - GPS (United States)
  - GLONASS (Russia)
  - Galileo (European Union)
  - BeiDou (China)



Transportation

- Portable navigation devices.
- Air, marine, and ground based vehicle navigation.

www.boeing.com

Garmin

www.wellandcanal.ca

Machine Control

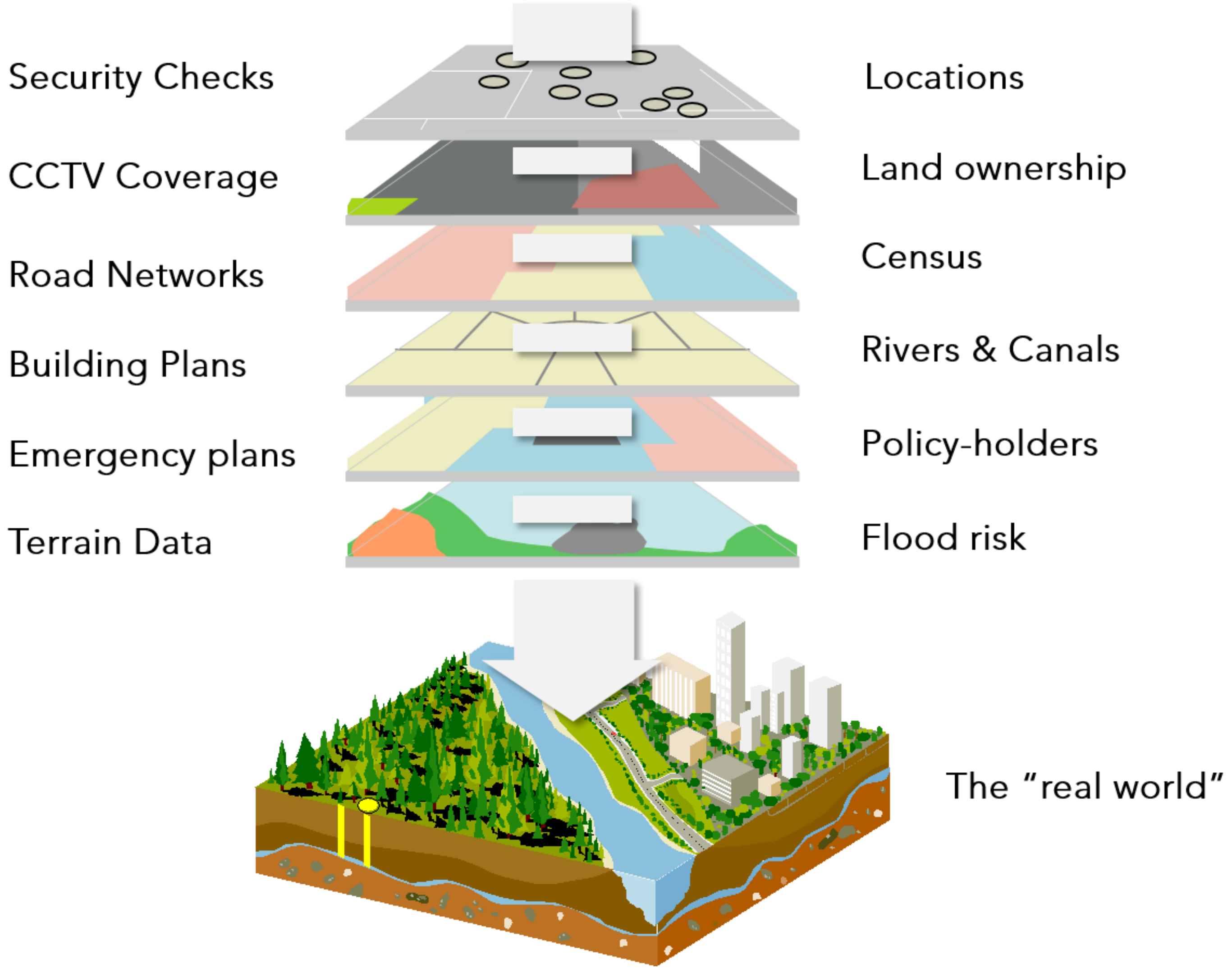
NovAtel Inc.

Thomas Morby, NovAtel Inc.

Surveying

Google Street View

GIS


Security Checks
CCTV Coverage
Road Networks
Building Plans
Emergency plans
Terrain Data
Locations
Land ownership
Census
Rivers & Canals
Policy-holders
Flood risk
The "real world"

Port Automation

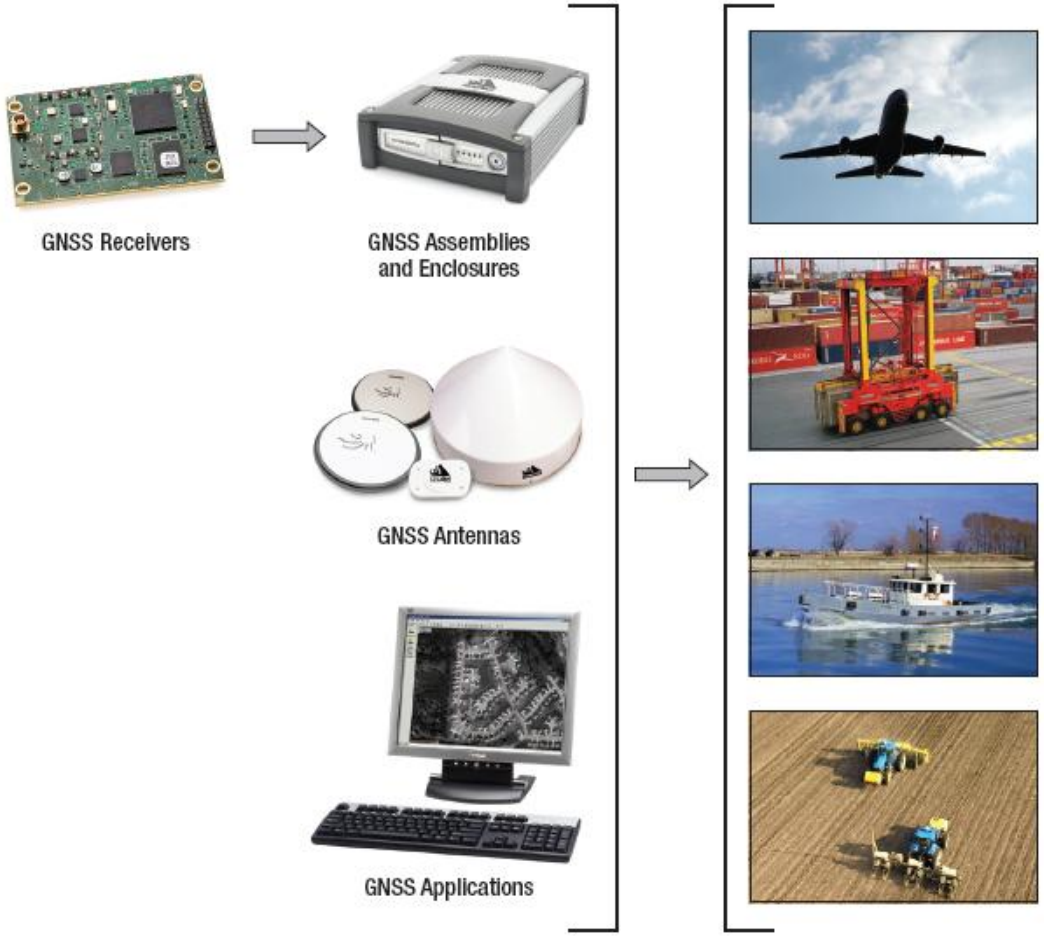
Adlay Eng. NovAtel Inc.

Defence

NASA

Equipment

- **There are different types of GNSS equipment available depending on the application and project requirements.**



Location based Service Applications for Automobiles

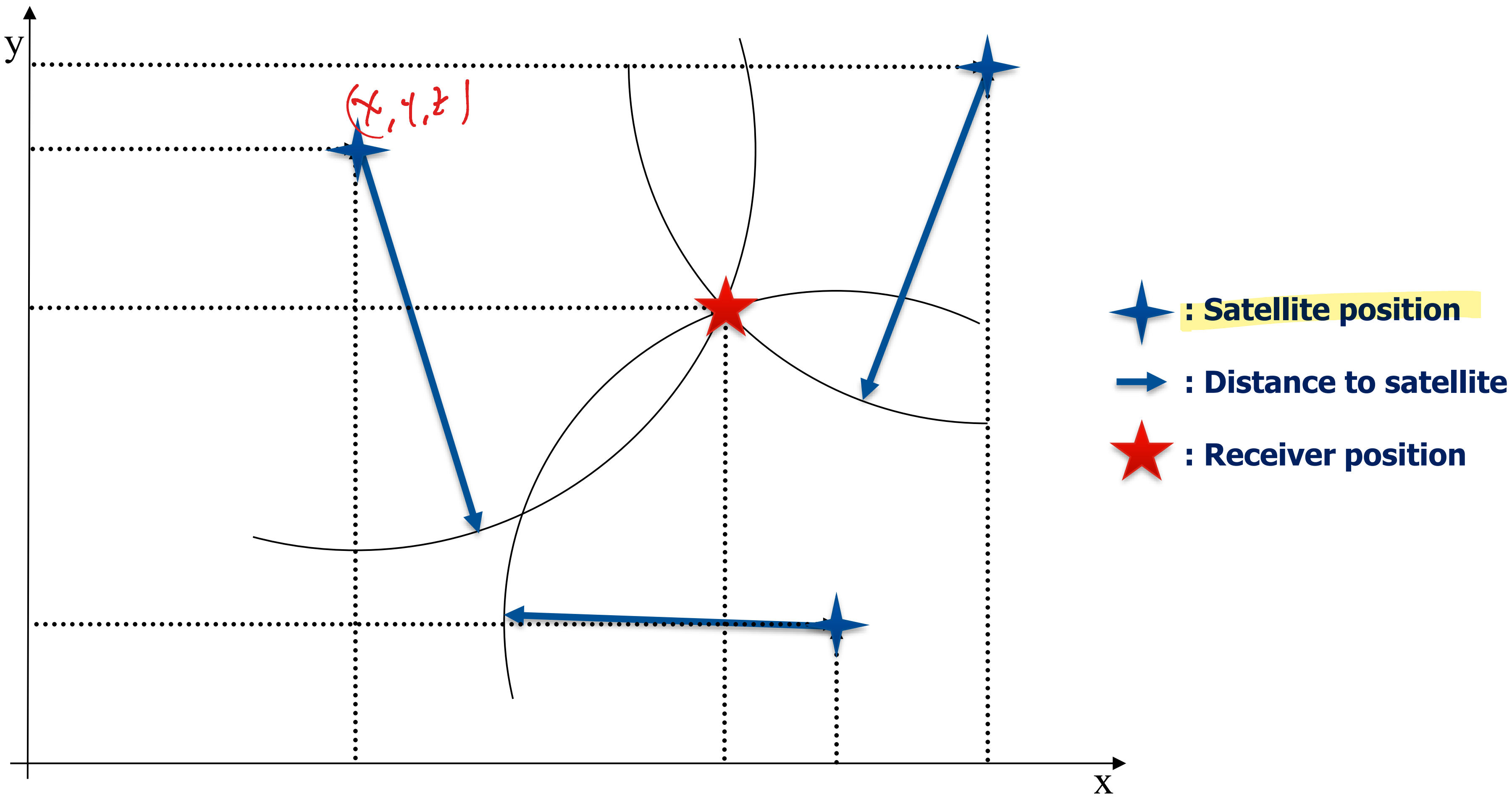
Location Based Services (LBS)

- Requiring the precise positioning information.

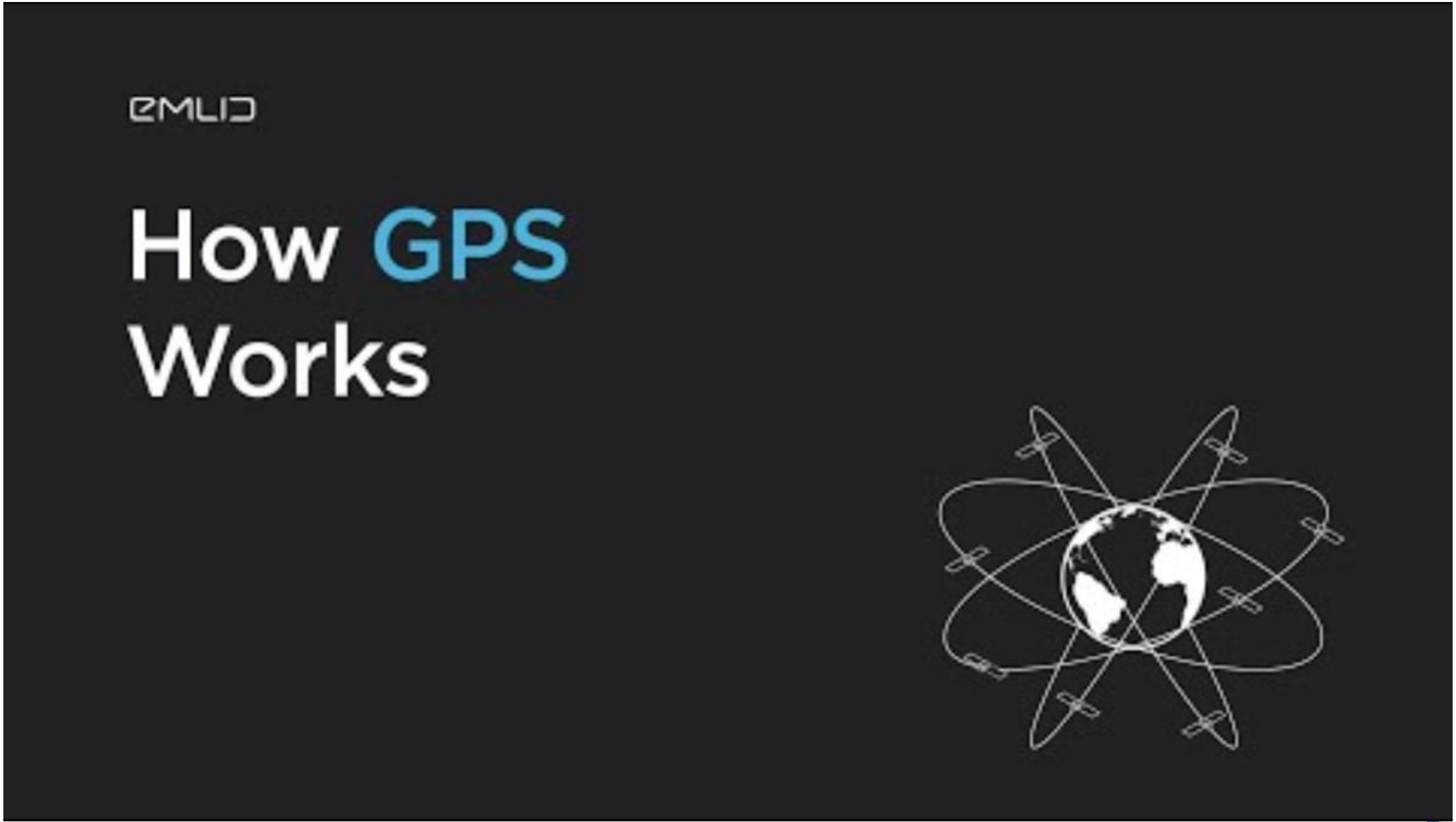
GNSS Basic

Global Navigation Satellite System (GNSS)

GNSS principle – Basic Trilateration



GNSS Principle – Basic Trilateration

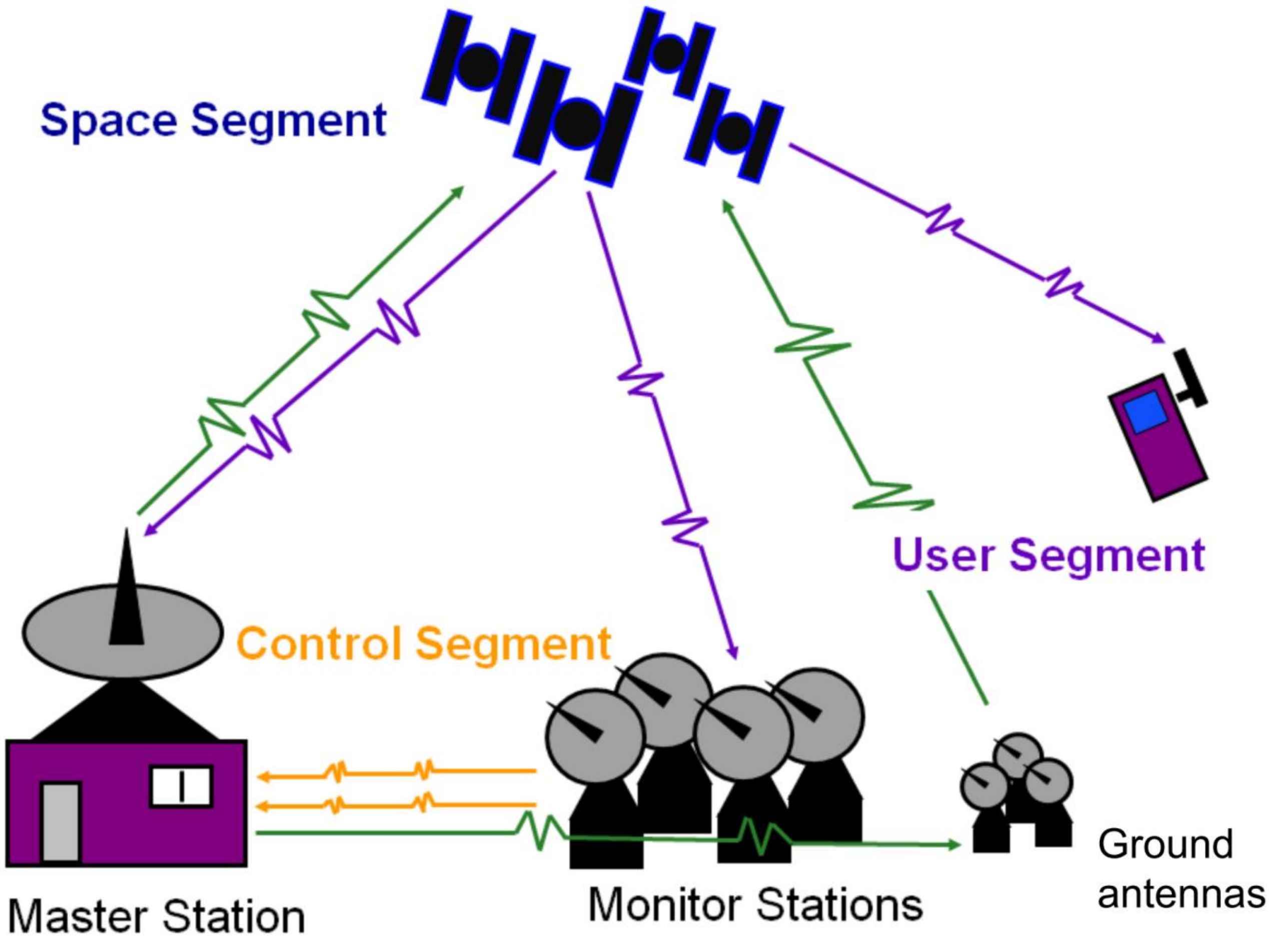


GNSS Structure

위성 3개 + 1

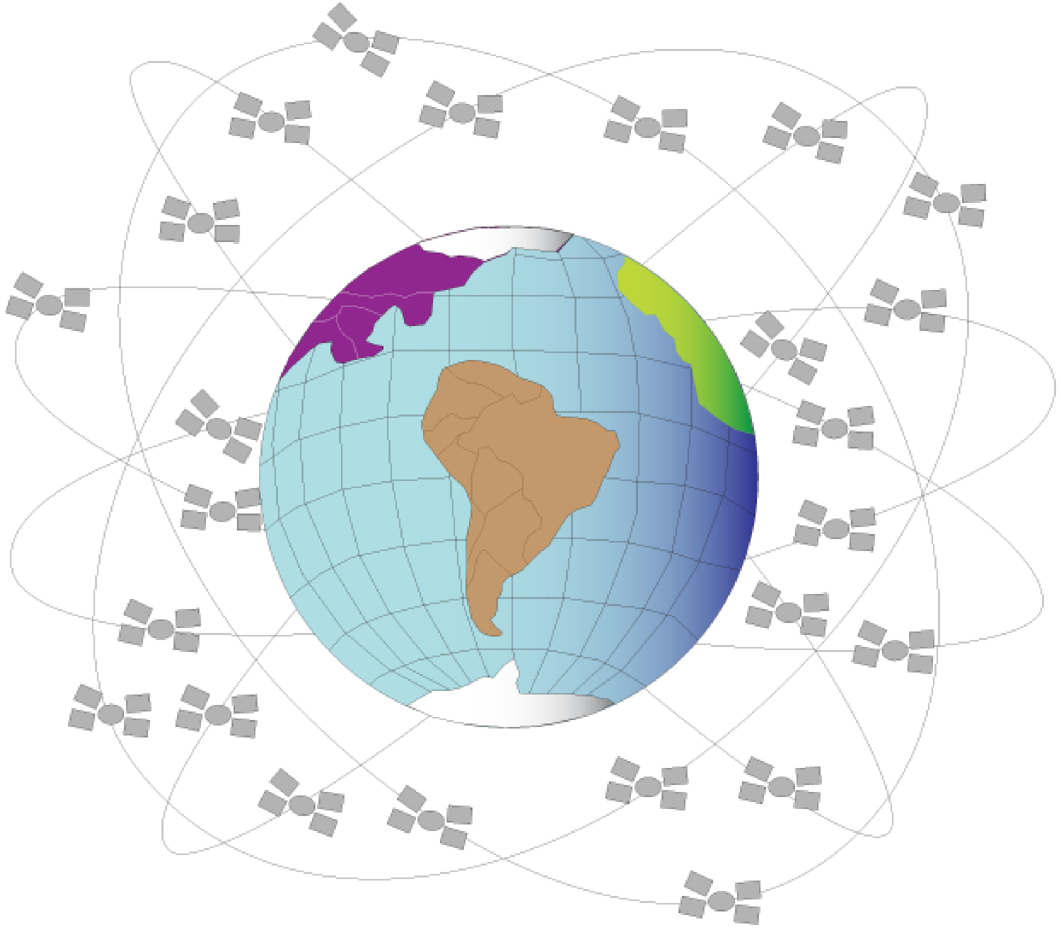
시계보정

- **GNSS satellite systems consists of three major segments:**
  - 1. Space Segment
  - 2. Control Segment
  - 3. User Segment



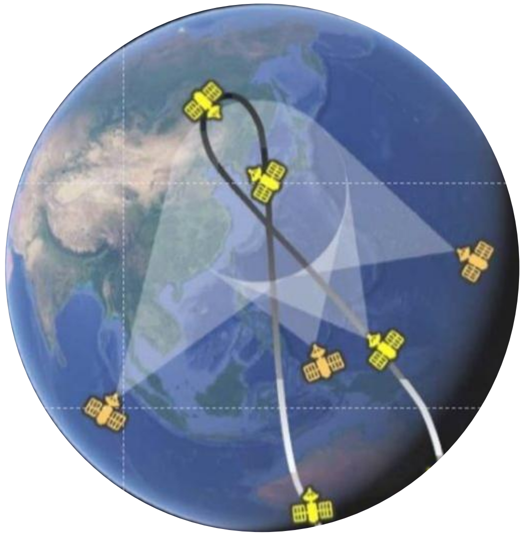
1. Space Segment

- Consists of GNSS satellites, orbiting about 20,000 km above the earth.
- Each GNSS has its own constellation of satellites.



Various navigation satellite systems

- **Global Navigation Satellite System (GNSS)**
  - Common name for positioning and navigation system using satellites.
  - Example
    - GPS (United States)
    - GLONASS (Russia)
    - Galileo (European Union)
    - BeiDou-2 (China)
- **Regional navigation satellite systems (RNSS)**
  - Region-limited system that provides service only in certain regions.
  - Example
    - BeiDou-1 (China)
    - IRNSS (India)
    - QZSS (Japan)
    - KPS (Korea)
- **Live satellite map**
  - https://in-the-sky.org/satmap_worldmap.php



Global Navigation Satellite Systems (GNSSs)

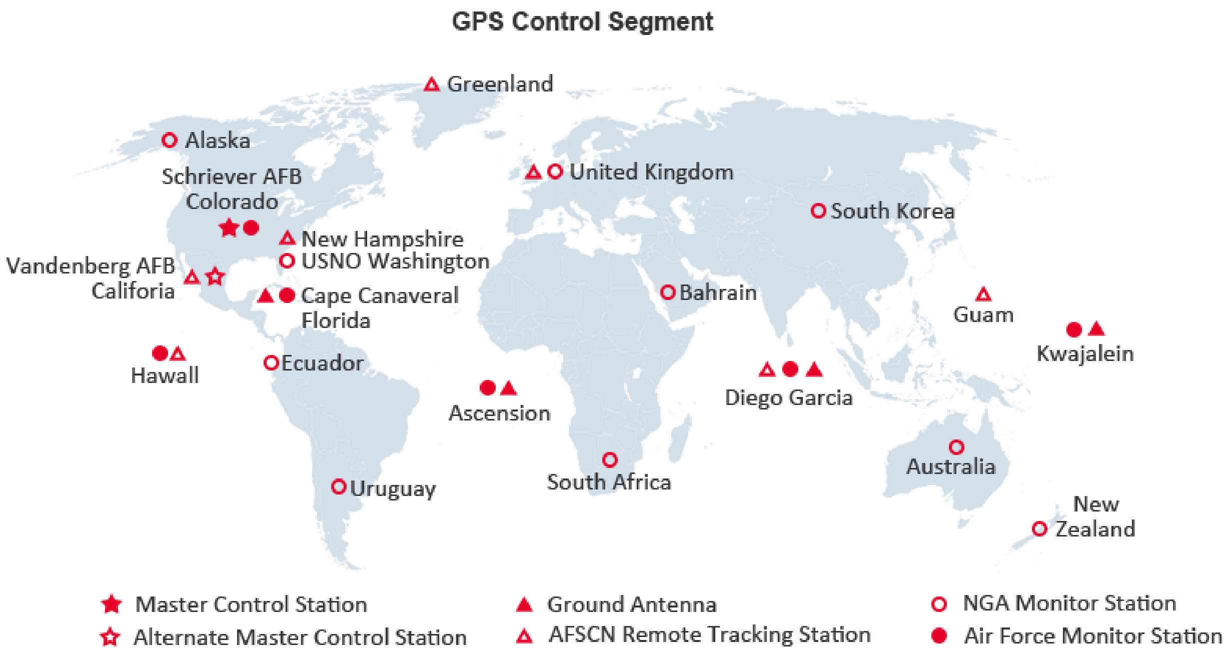
- **GPS (Global Positioning System)**
  - Owned by the United States government and operated by the United States Space Force.
  - Current number of usable satellites is 32.
- **GLONASS**
  - A Russian satellite navigation system that operating as part of a radionavigation-satellite service.
  - Current number of usable satellites is 27.
- **Galileo**
  - A GNSS that went live in 2016, created by the EU through the European Space Agency (ESA), operated by the European Union Agency for the Space Programme (EUSPA).
  - Current number of usable satellites is 22.
- **BaiDou-3**
  - Owned and operated by the China National Space Administration and provides full global coverage for timing and navigation.
  - Current number of usable satellites is 34.

Regional Navigation Satellite Systems

- **BeiDou-1**
  - Chinese regional (Asia-Pacific, 16 satellites) network to be expanded into the whole BeiDou-2 global system which consists of all 35 satellites by 2020.
- **NAVIC (NAVigation with Indian Constellation, India)**
  - An autonomous regional satellite navigation system developed by Indian Space Research Organization (ISRO) which would be under the total control of Indian government.
- **QZSS (Quasi-Zenith Satellite System, Japan)**
  - A proposed four-satellite regional time transfer system and enhancement for GPS covering Japan and the Asia-Oceania regions.
- **KPS (Korean Positioning System)**
  - The Korean Aerospace Research Institute is participating in the planning, and development is scheduled to begin in 2022 and operation begins in 2035.

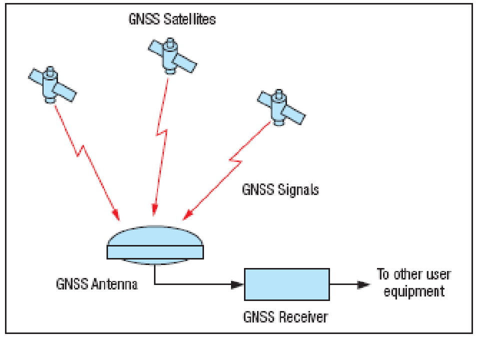
2. Control Segment

- **The control segment consists of three types of ground-based stations:**
  - **Master control stations** adjust the satellites orbit parameters and on-board high-precision clocks when necessary to maintain accuracy.
  - **Monitor stations** monitor the satellites signal and status and relay this information to the master control station.
  - **Uploading stations** uploads any change in satellite status back to the satellites.



User Segment

- **User segment consists of GNSS antennas and receivers used to determine information such as position, velocity, and time.**

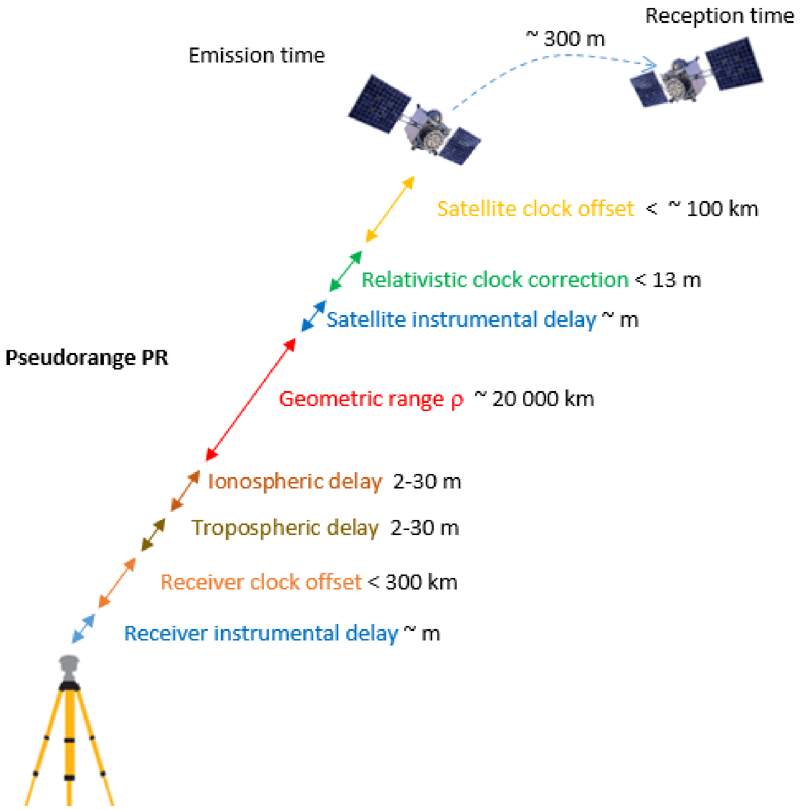


GNSS error

Sources of Error in GNSS

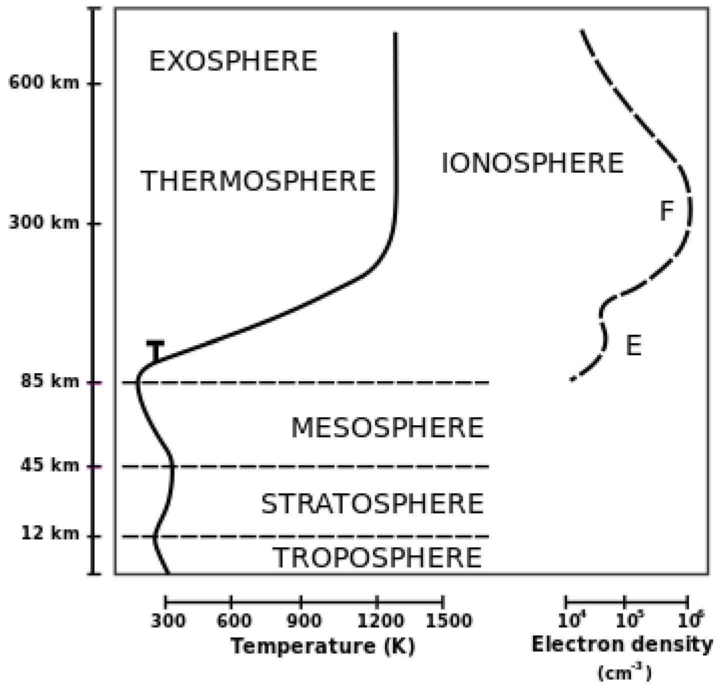
- **GNSS positioning is based on the pseudorange between satellites and receivers.**
  - $R_P = \rho + c(dt_r - dt^s) + T + \alpha_f STEC + K_{P,r} - K_P^S + M_P + \varepsilon_P$

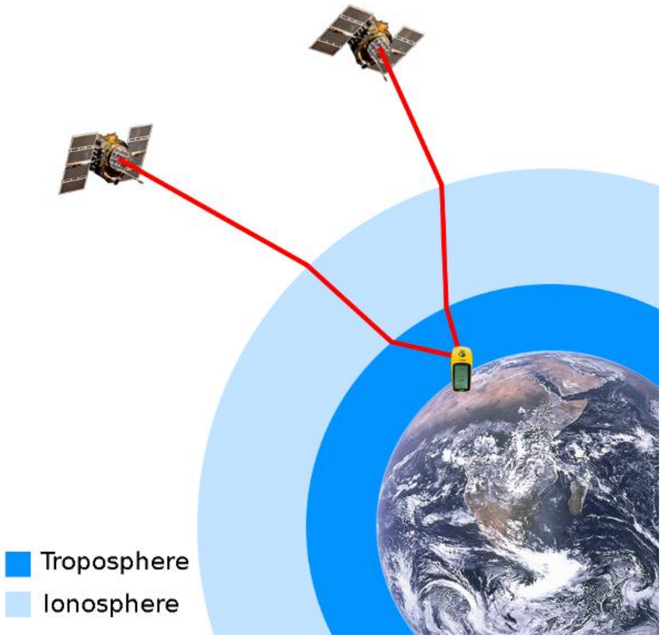
    error term
    - $R_P: measastured\ distance$
    - $\rho: true\ distnace$
    - $c: light\ speed$
    - $dt_r, dt^s: receiver,\ satellite\ clock\ offset$
    - $T: tropospheric\ delay$ 대류권
    - $\alpha_f STEC: frequency - dependent\ ionosheric\ delay$ 전리층
    - $K_{P,r}, K_P^S: receiver\ and\ satellite\ instrumental\ delay$
    - $M_P: multipath\ error$



Ionospheric and Tropospheric Errors

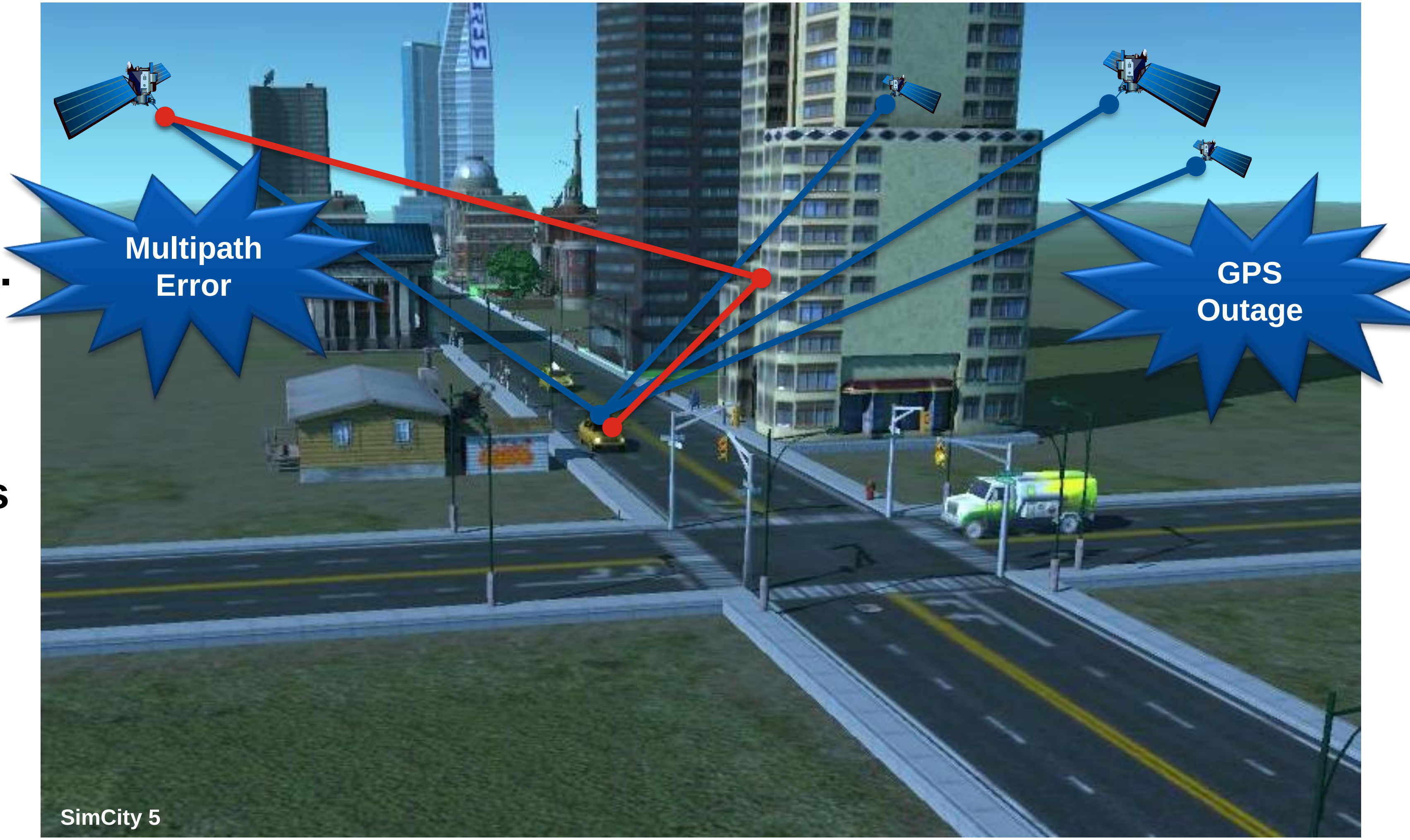
- When the GNSS signal passes through Ionospheric layer, its interaction with ions reduces its speed and therefore introduces an error.
- Tropospheric errors are caused by temperature, density, pressure or humidity changes.





Multipath Error

- Multipath errors appear when a GNSS signal arrives at the receiver GNSS antenna after having been reflected from an object such as the surface of a building.
- The reflected signal clearly has to travel further to reach the antenna and so it arrives with a slight delay.
- This delay can cause positional error.

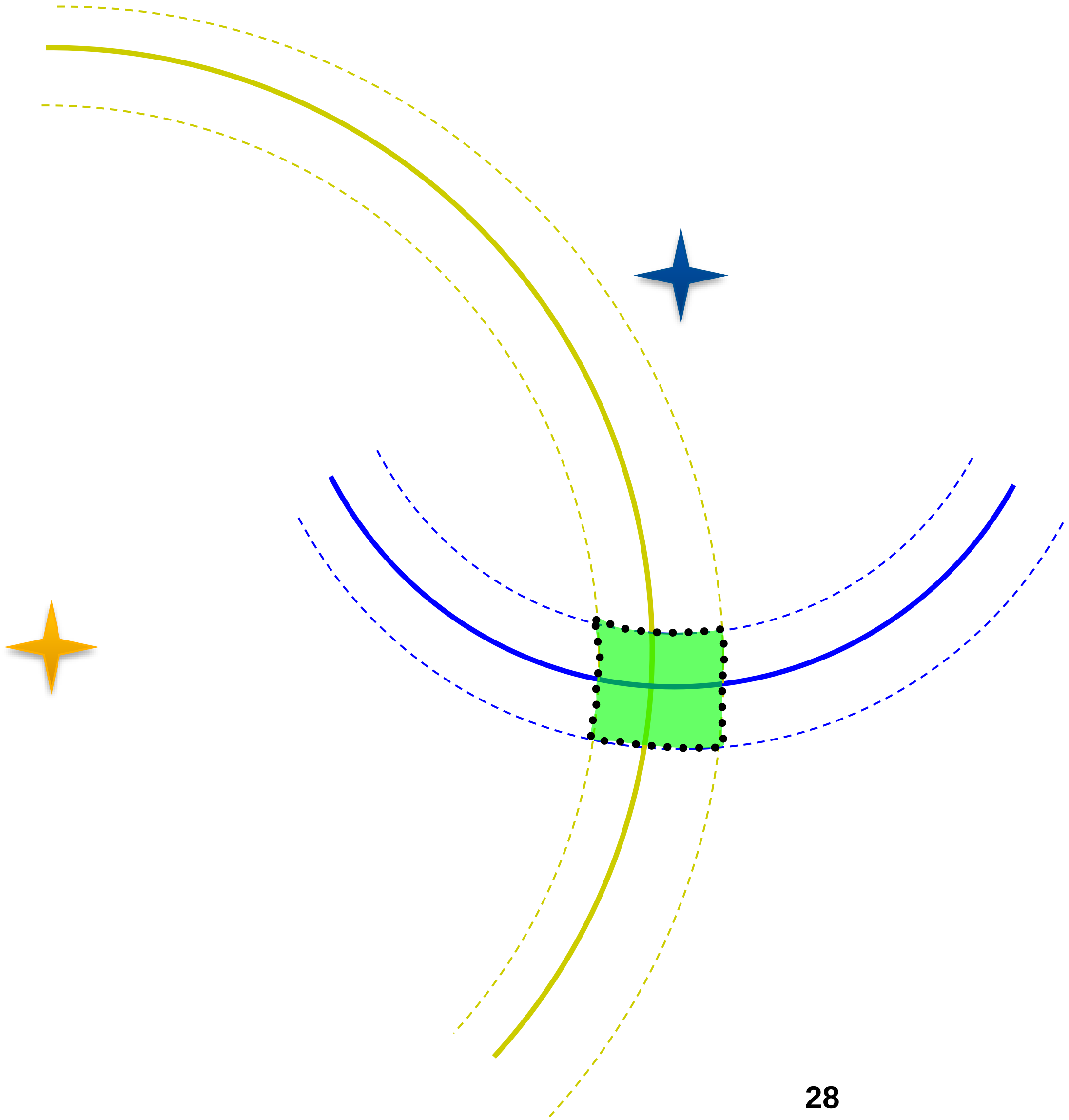


DOP (Dilution of Precision)

- **DOP error may be caused by the relative positions in three-dimensional space of the satellites used to calculate a position.**
  - Poor DOP values mean ‘bad’ positioning of satellites.
  - On the contrary, ‘well’ distributed satellites produce good values.

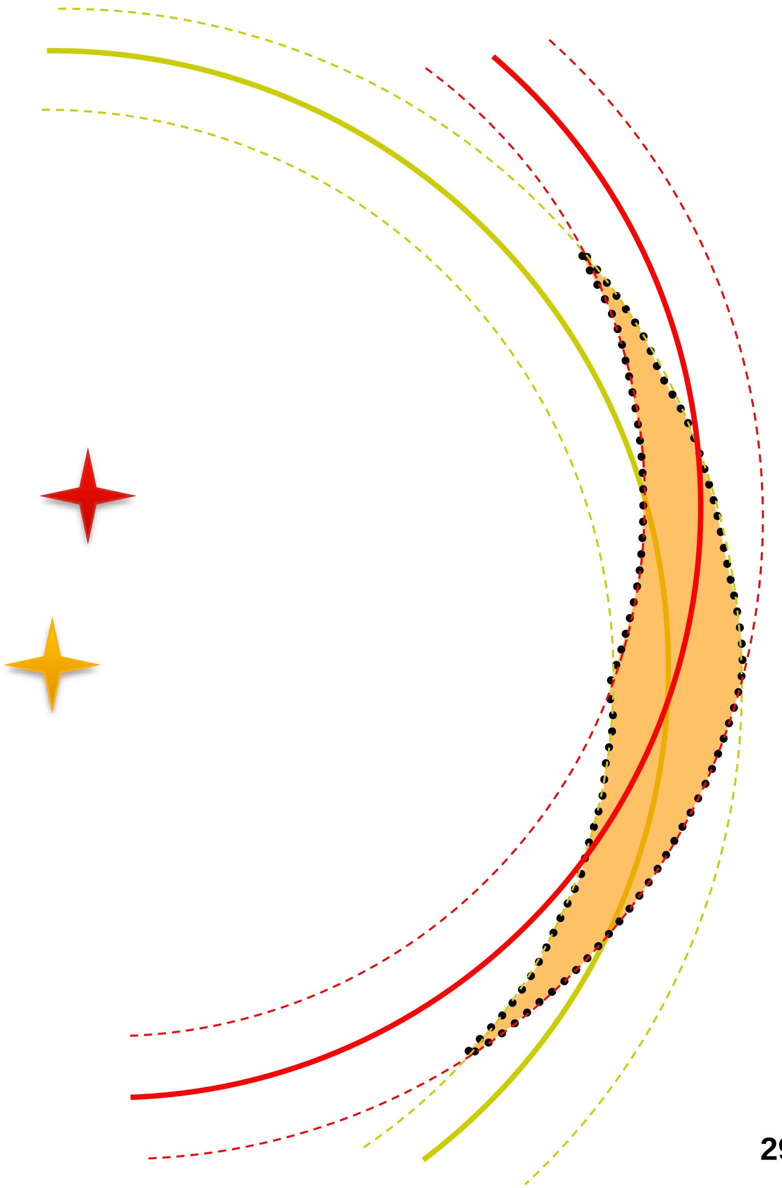
- **Types of DOP**
  - HDOP: Horizontal Dilution Of Precision error. Measure of accuracy in 2-D position, for example, Latitude and Longitude.
  - VDOP: Velocity Dilution Of Precision error. Measure of accuracy in 1-D position, Height.
  - PDOP: Position Dilution Of Precision error. Measure of accuracy in 3-D position. It is also called spherical DOP.
  - TDOP: Time Dilution Of Precision error. Measure of accuracy in Time.

PDOP (Position Dilution of Precision) – Good



Good

PDOP (Position Dilution of Precision) – Bad



Bad

Improved GNSS

보정

Base Station 에 의한

Reference base station-based correction

Reference base station-based error correction

- The error is calculated using the difference between the **known exact position** of a reference station and the actual measured GNSS position.
- This error information is transmitted to the mobile station (rover) and applied to the mobile station's GNSS signal to correct the error.

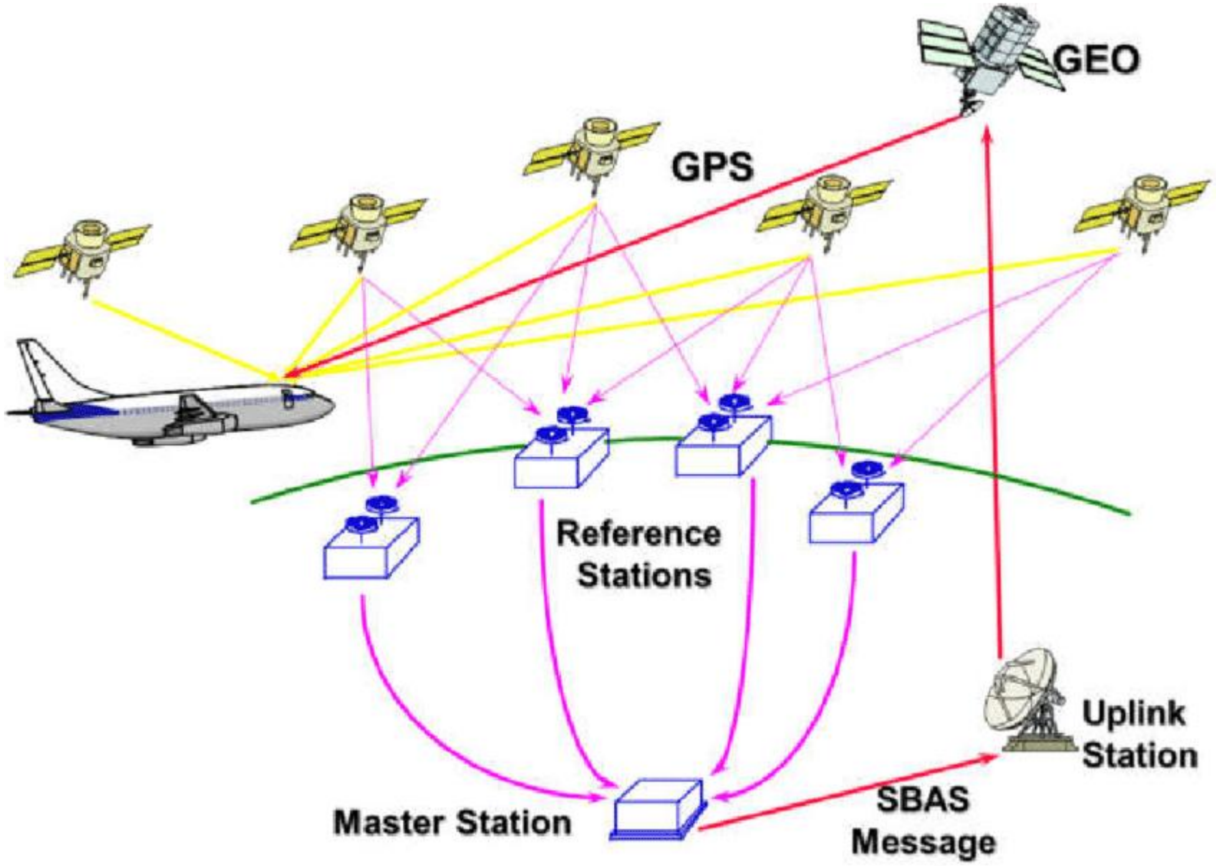
Accuracy

- Differential-GNSS (DGNSS)
  - Code based range detection
  - 0.5 ~ 5m
- Real-Time Kinematic (RTK)
  - Carrier phase range detection
  - 0.01~0.1 m

Satellite-Based Augmentation System (SBAS)

- **A system that uses satellites to improve the accuracy of GNSS signals.**
  - Error information collected from multiple ground reference stations.
  - Data is analyzed at central processing station.
  - Correction information is transmitted to GNSS users via SBAS satellites.

- **Accuracy**
  - Approximately 1m



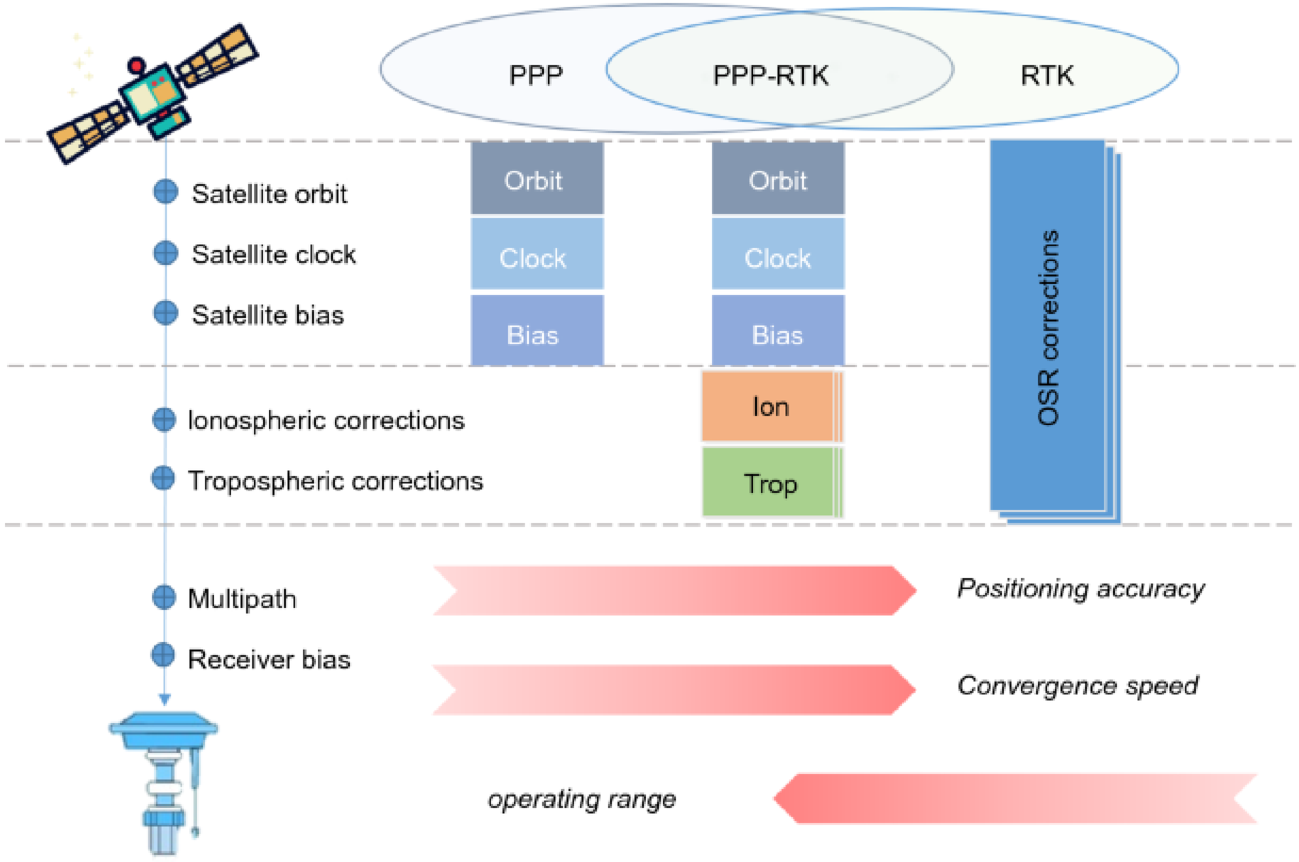
Precise Point Positioning (PPP)

Single Receiver

- Unlike DGPS or RTK, PPP can achieve high accuracy with a single GNSS receiver.
- PPP does not rely on a reference station, making it effective worldwide.

Precise Data

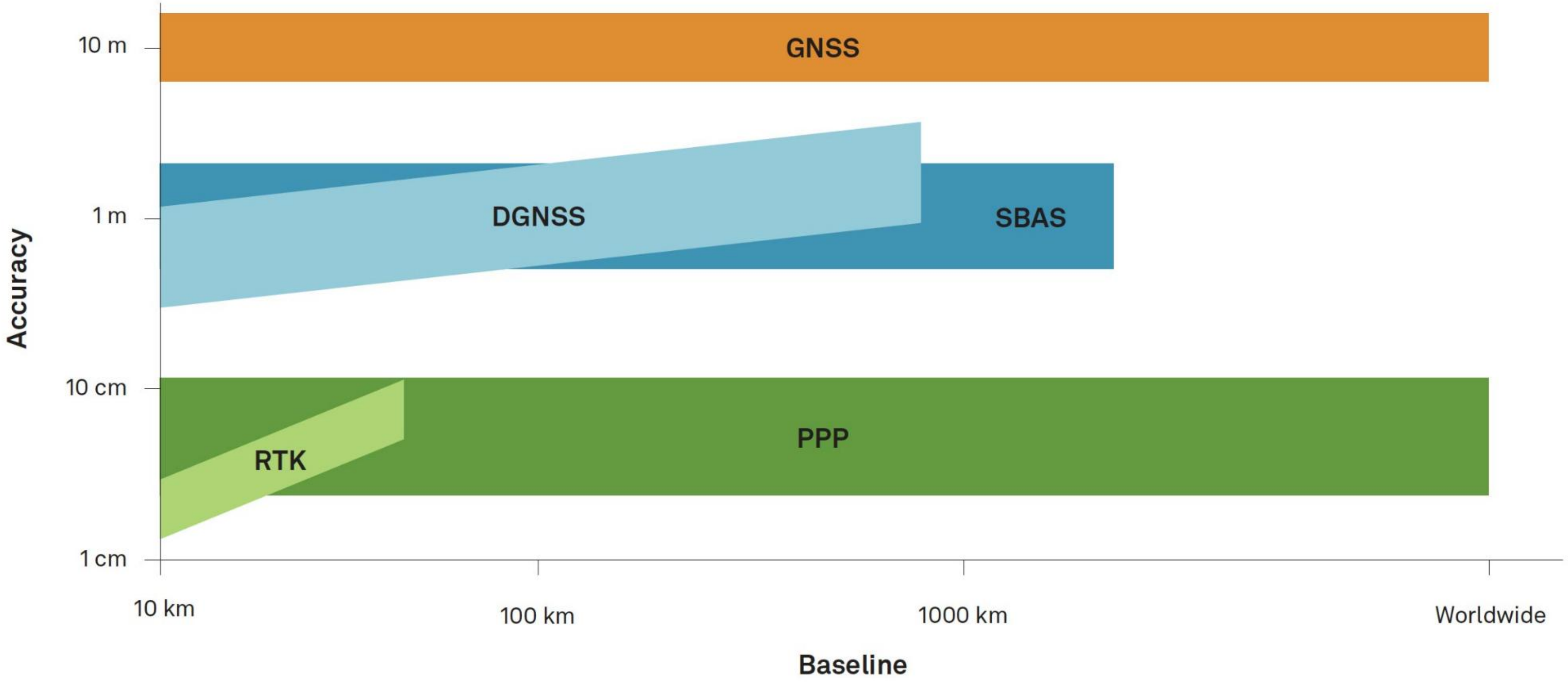
- PPP utilizes corrections data from a global network of tracking stations. The data is processed by international agencies such as the International GNSS Service (IGS).



Improved GNSS

- **Classic GNSS accuracy**
  - In the outdoor, the best achieve is 2.0 meters.

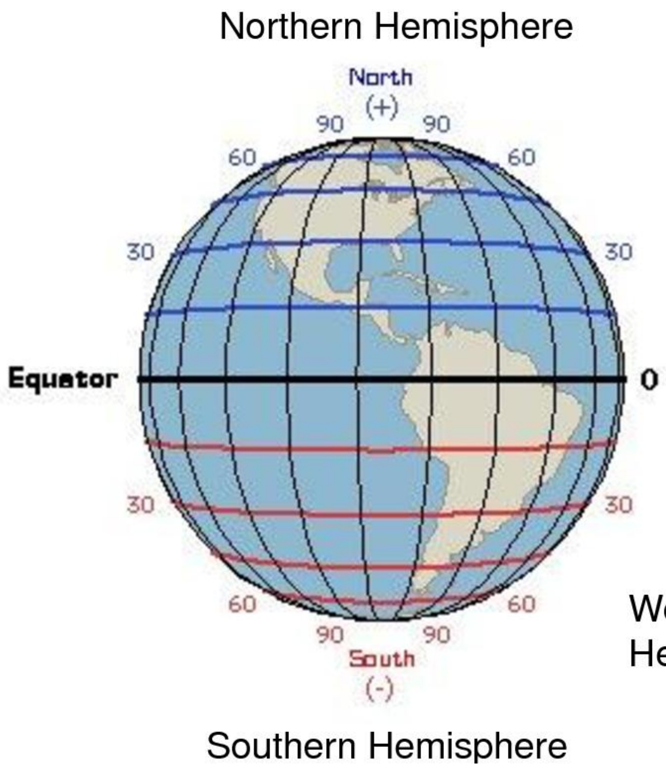
- **Error correction methods**
  - DGNSS
  - RTK
  - SBAS
  - PPP



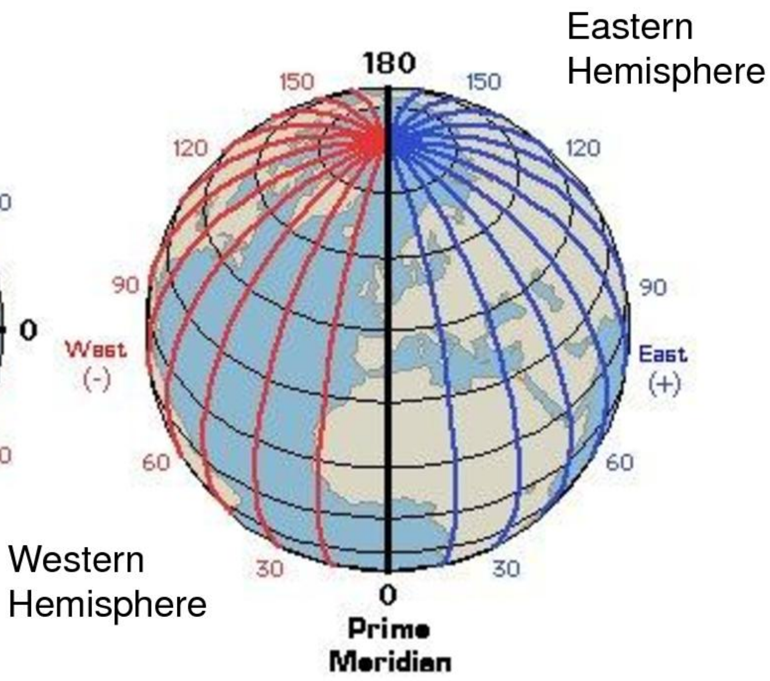
Geographic coordinate system

Geographic Coordinate System (1/4)

- **A coordinate system that enables every location on Earth to be specified by a set of numbers, letters or symbols.**
  - Horizontal position: latitude & longitude
  - Vertical position: height (altitude or elevation)



Latitude



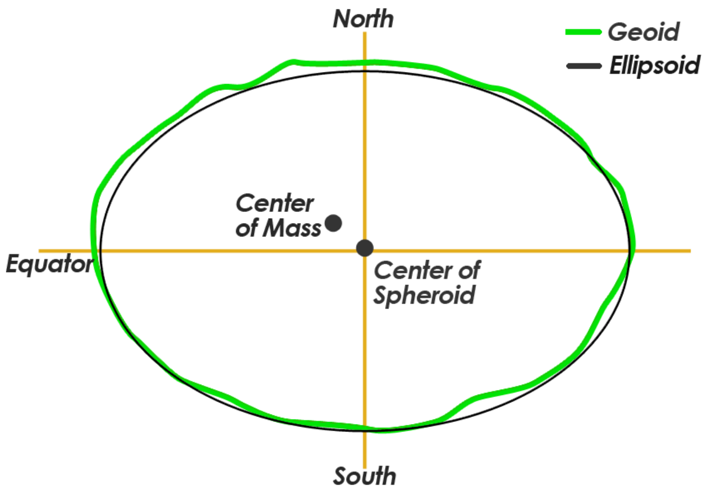
Longitude

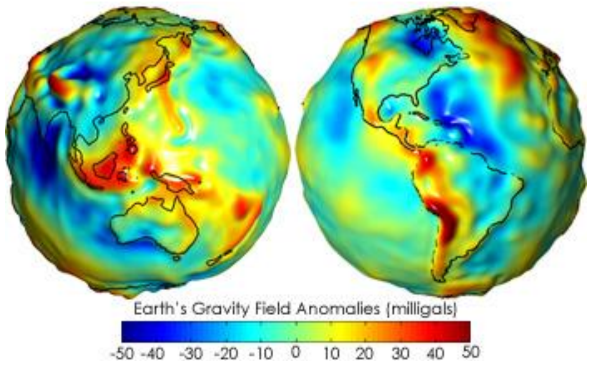
서울
37. - -
127. - -

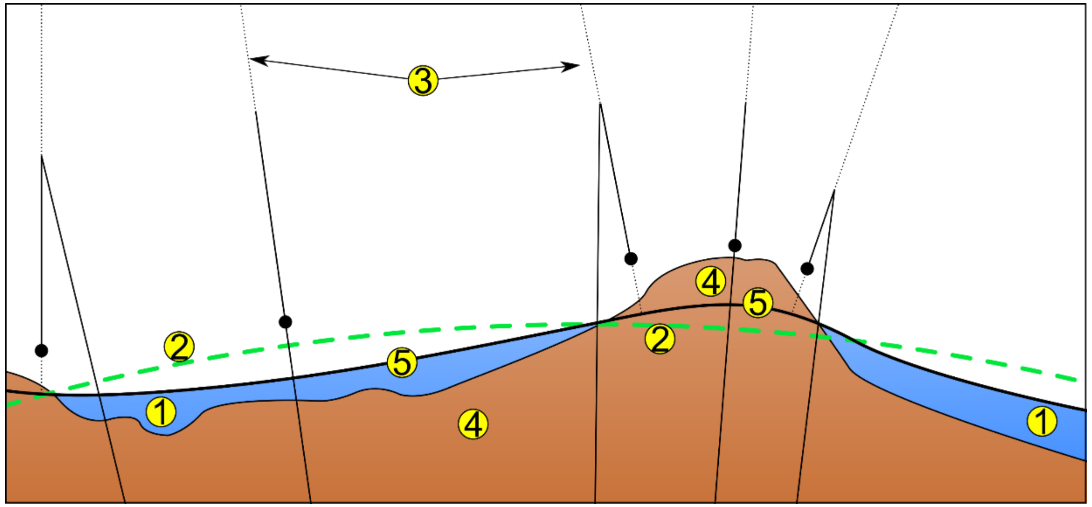
단위
각도

Geographic Coordinate System (2/4)

- Geoid
  - The shape of the ocean surface if only Earth's gravity and spin affected it, with no winds or tides.





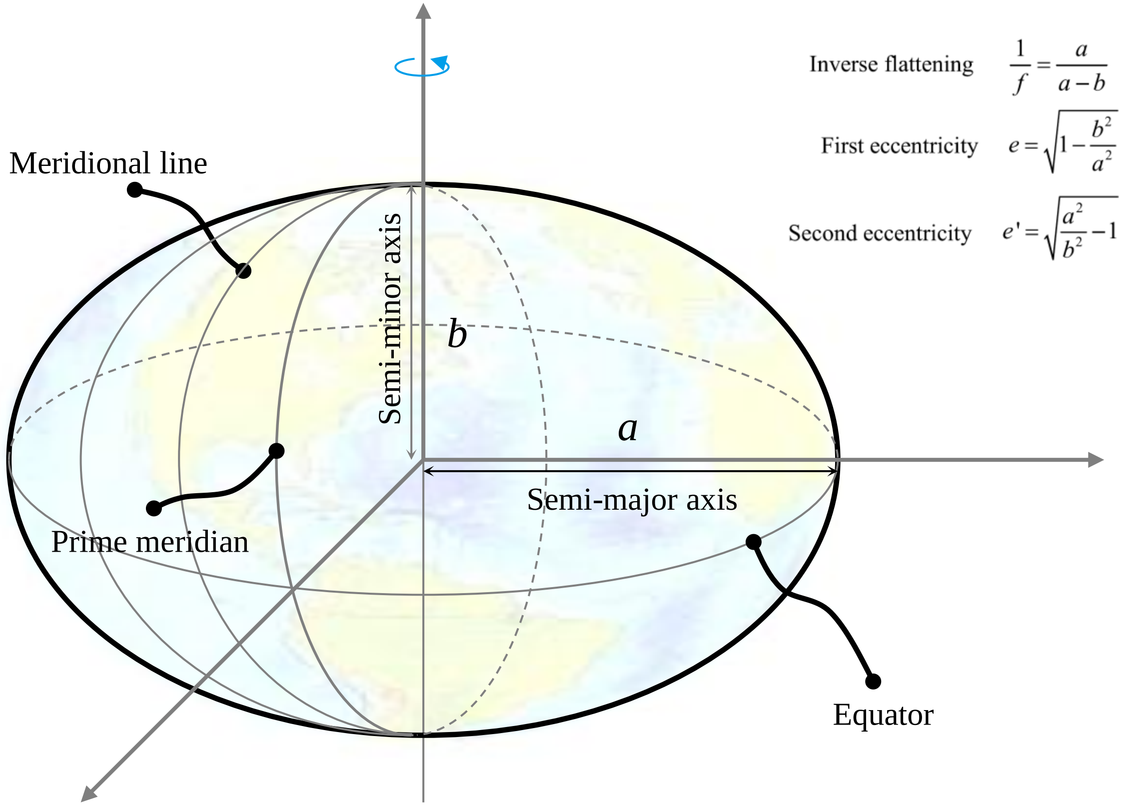


1. Ocean 2. Reference ellipsoid 3. Local plumb line 4. Continent 5. Geoid

Geographic Coordinate System (3/4)

Mathematical earth model

- Map-makers choose a reference ellipsoid with a given origin and orientation that best fits their need for the area they are mapping.
- They then choose the most appropriate mapping of the spherical coordinate system onto that ellipsoid, called a terrestrial reference system or geodetic datum.



Inverse flattening $\frac{1}{f} = \frac{a}{a-b}$

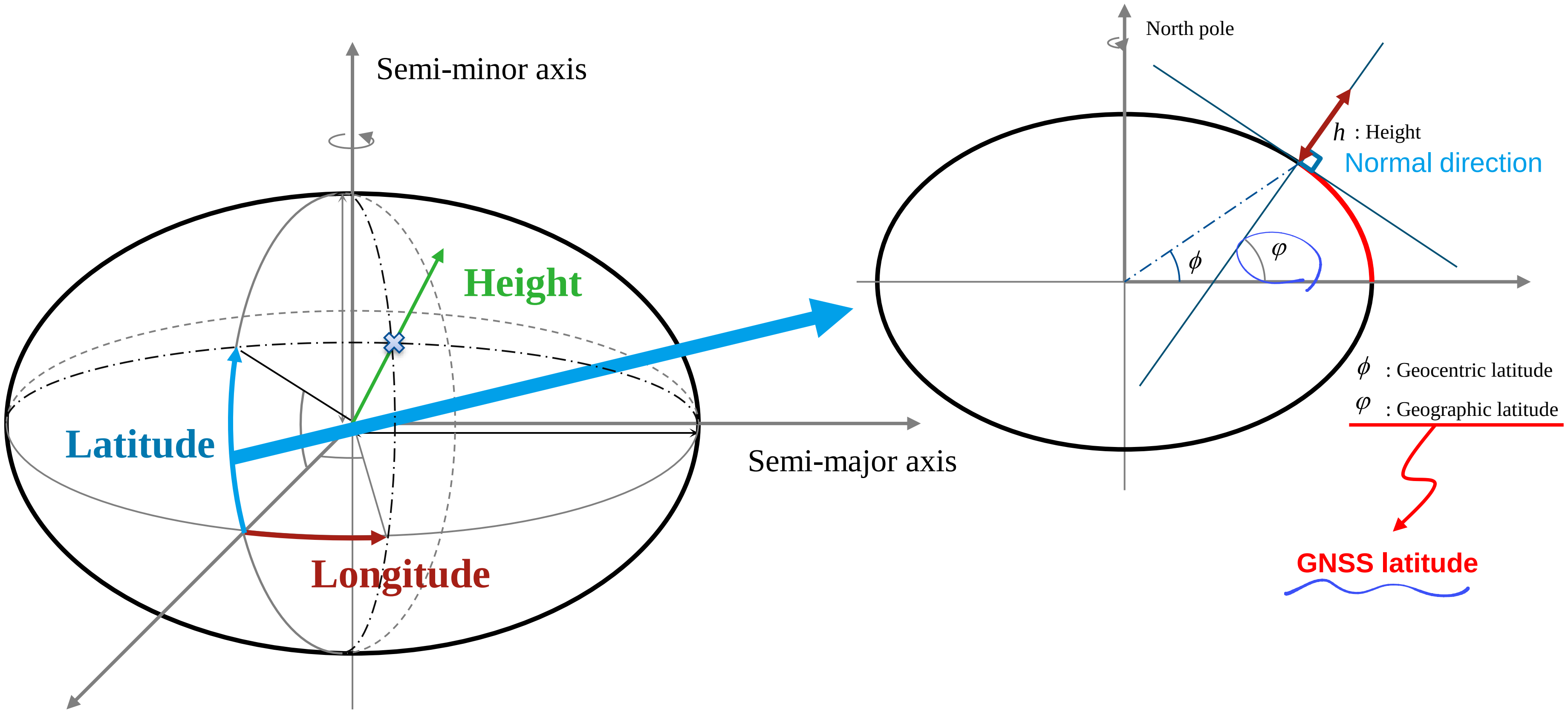
First eccentricity $e = \sqrt{1 - \frac{b^2}{a^2}}$

Second eccentricity $e' = \sqrt{\frac{a^2}{b^2} - 1}$

ELLIPSE_N	ELLIPSE_C	ELLIPSE_A	ELLIPSE_B	ELLIPSE_F
Airy	AA	6377563.396	6356256.909	299.3249646
Modified Airy	AM	6377340.189	6356034.448	299.3249646
Australian National	AN	6378160	6356774.719	298.25
Bessel 1841	BR	6377397.155	6356078.963	299.1528128
Bessel 1841(Namibia)	BN	6377483.865	6356165.383	299.1528128
Clarke 1866	CC	6378206.4	6356583.8	294.9786982
Clarke 1880	CD	6378249.145	6356514.87	293.465
Everest	EA	6377276.345	6356075.413	300.8017
Everest (E. Malasia--Brunei)	EB	6377298.556	6356097.55	300.8017
Everest 1956 (India)	EC	6377301.243	6356100.228	300.8017
Everest 1969 (West Malasia)	ED	6377295.664	6356094.668	300.8017
Everest 1948 (W.Mals. & Sing.)	EE	6377304.063	6356103.039	300.8017
Everest (Pakistan)	EF	6377309.613	6356109.571	300.8017
Mod. Fischer 1960 (South Asia)	FA	6378155	6356773.32	298.3
GRS 80	RF	6378137	6356752.314	298.2572221
Helmert 1906	HE	6378200	6356818.17	298.3
Hough	HO	6378270	6356794.343	297
Indonesian 1974	ID	6378160	6356774.504	298.247
International	IN	6378388	6356911.946	297
Krassovsky	KA	6378245	6356863.019	298.3
South American 1969	SA	6378160	6356774.719	298.25
WGS 72	WD	6378135	6356750.52	298.26
WGS 84	WE	6378137	6356752.314	298.2572236
MARS	MA	3398627	3376200	169.8

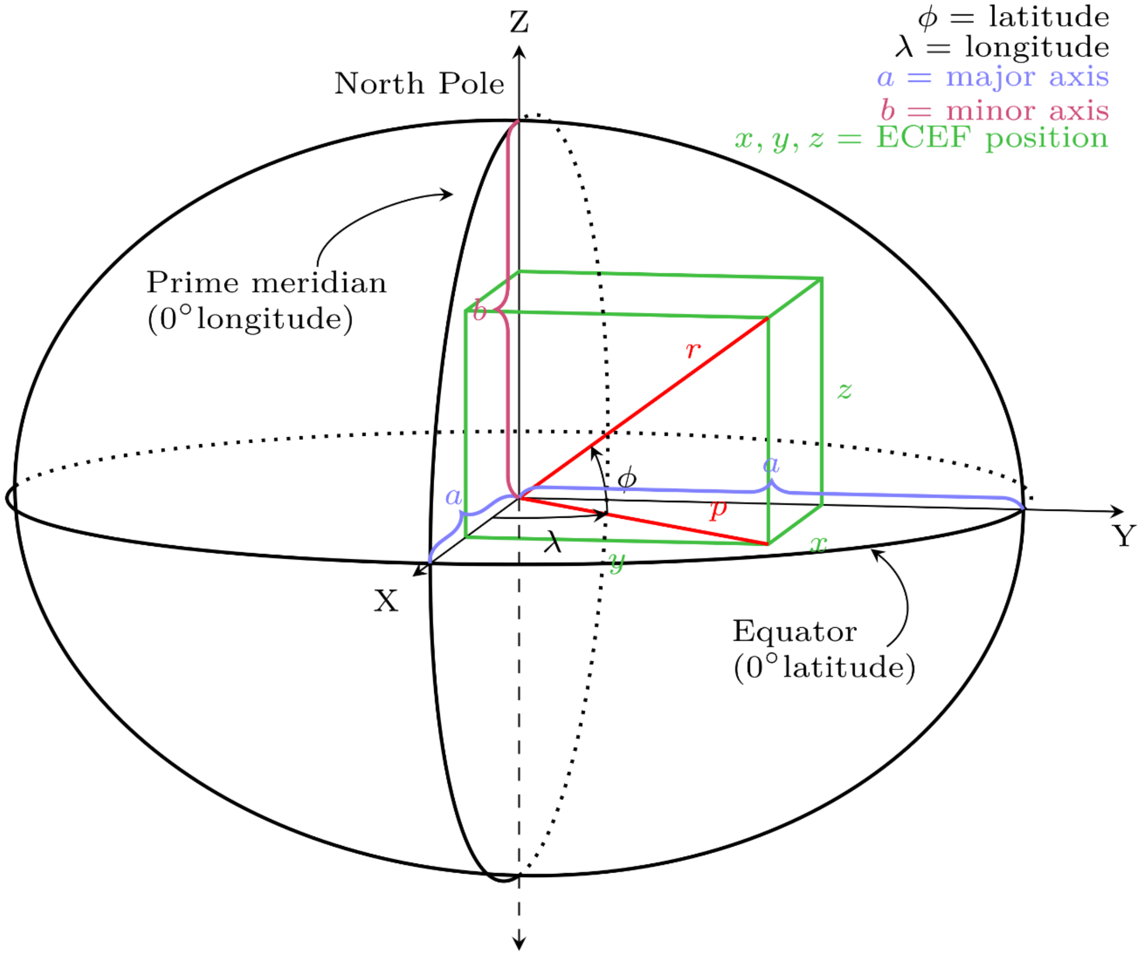
Geographic Coordinate System (4/4)

Geographic latitude, longitude and height



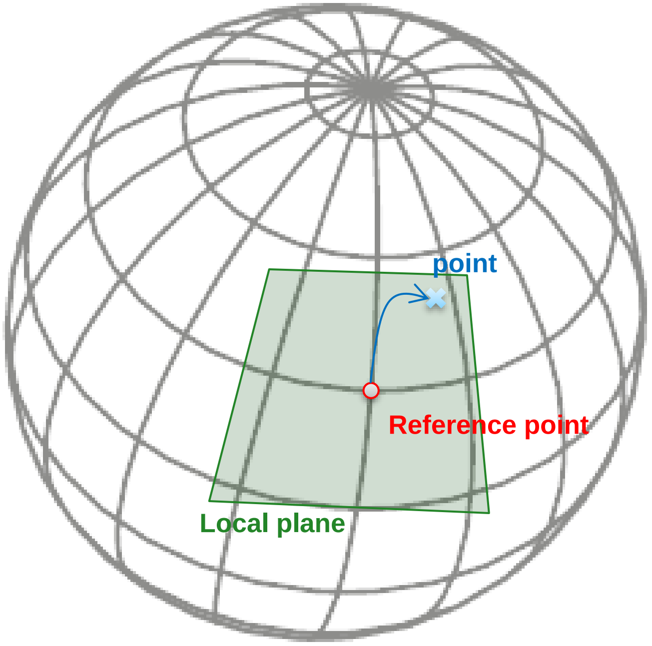
3D Cartesian Coordinate System (1/2)

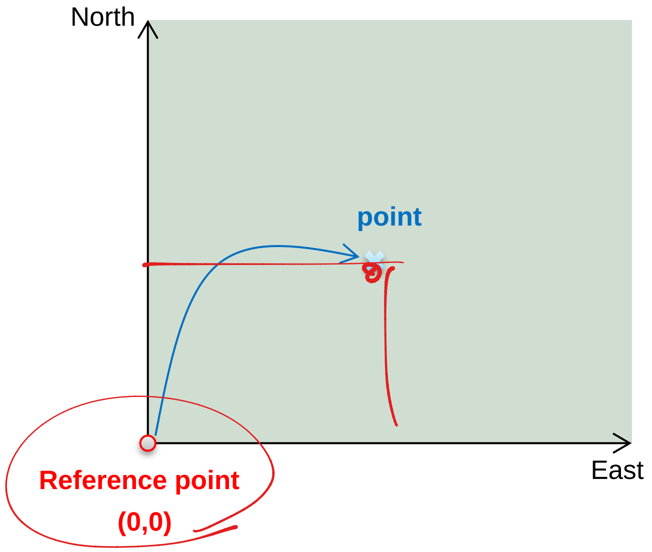
- Earth-Centered, Earth-fixed (ECEF)
  - The origin at the center of mass of the Earth, a point close to the Earth's center of figure.
  - The Z axis on the line between the North and South Poles, with positive values increasing northward (but does not exactly coincide with the Earth's rotational axis).
  - The X and Y axes in the plane of the Equator.
  - The X axis passing through extending from 180 degrees longitude at the Equator (negative) to 0 degrees longitude (prime meridian) at the Equator (positive).
  - The Y axis passing through extending from 90 degrees west longitude at the Equator (negative) to 90 degrees east longitude at the Equator (positive).



3D Cartesian Coordinate System (2/2)

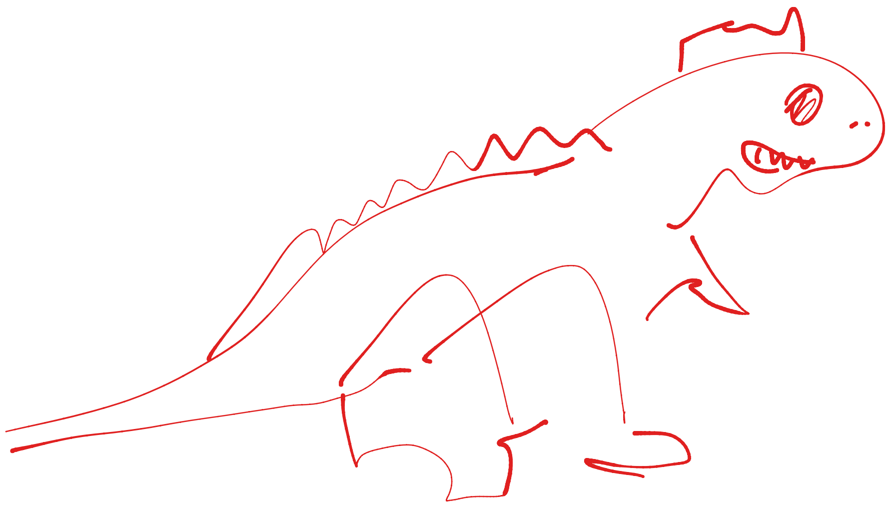
- Local tangent plane
  - ENU(East-North-Up) coordinate
  - Local Cartesian coordinate on approximated plane of the reference point





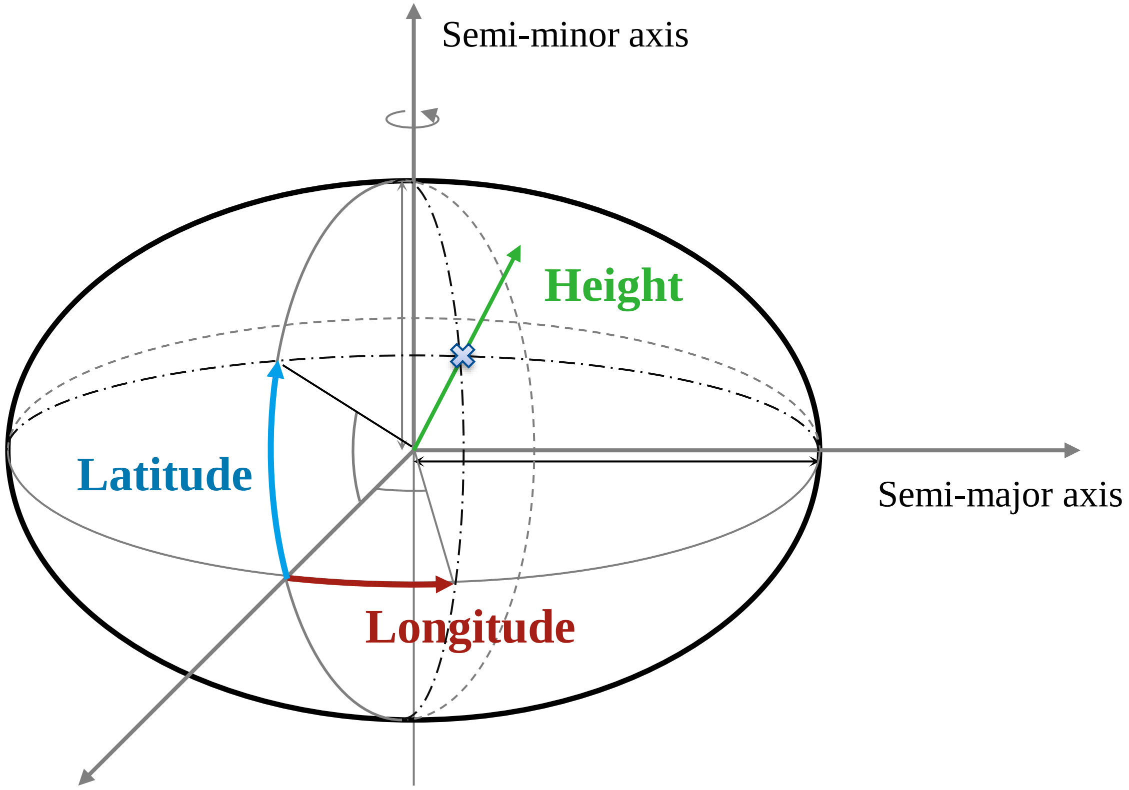
Lati, Lag..

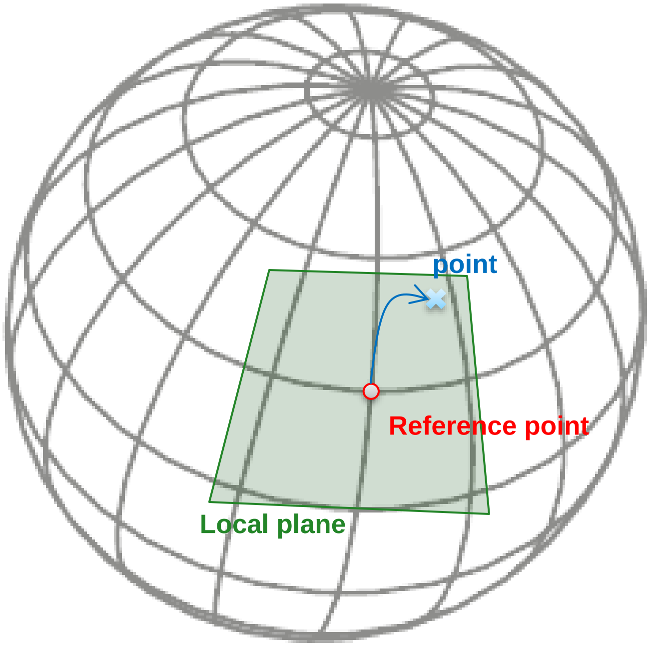
Geographic coordinate conversion



Geographic Coordinate Conversion

- **Coordinate conversion between**
  - Geographic coordinate (latitude, longitude, altitude)
  - and local tangent plane

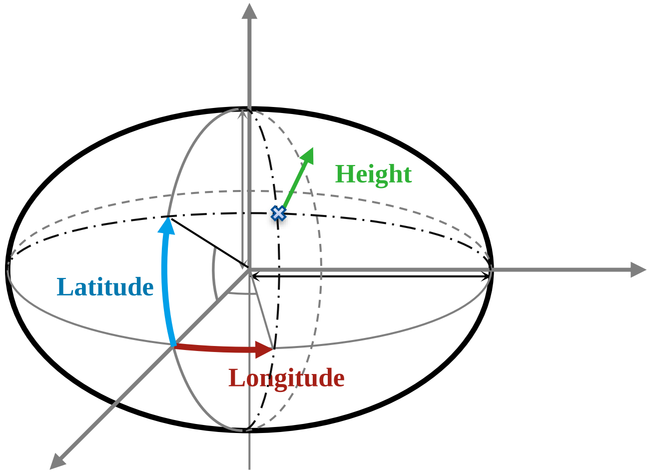


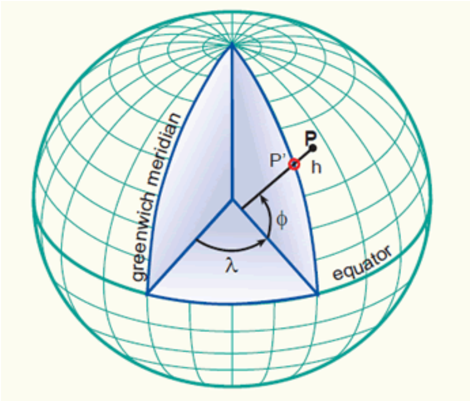


Previous Approaches (1/4)

Converting via the ECEF coordinate

- ECEF(Earth Centered Earth Fixed) coordinate
  - Cartesian coordinate which the origin of coordinate is exist on earth center.





Convert to ECEF point

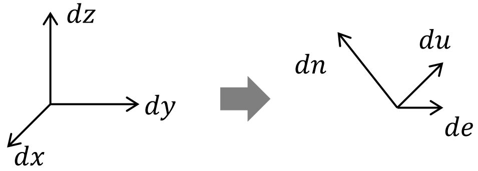
$$x = \left(\frac{a}{\chi} + h\right) \cdot \cos\varphi \cdot \cos\lambda$$

$$y = \left(\frac{a}{\chi} + h\right) \cdot \cos\varphi \cdot \sin\lambda$$

$$z = \left(\frac{a(1-e^2)}{\chi} + h\right) \cdot \sin\varphi$$

$$(\chi = \sqrt{1 - e^2 \cdot \sin^2\varphi},\ a : const)$$

Rotation



$$\begin{pmatrix} de \\ dn \\ du \end{pmatrix} = \begin{pmatrix} -\sin\lambda & \cos\lambda & 0 \\ -\sin\varphi \cdot \cos\lambda & -\sin\varphi \cdot \sin\lambda & \cos\varphi \\ \cos\varphi \cdot \cos\lambda & \cos\varphi \cdot \sin\lambda & \sin\varphi \end{pmatrix} \cdot \begin{pmatrix} dx \\ dy \\ dz \end{pmatrix}$$

$$\therefore\ de = \left(\frac{a}{\chi} + h\right) \cdot \cos\varphi \cdot \mathrm{d}\lambda - \left(\frac{a\left(1-e^2\right)}{\chi^3} + h\right) \cdot \sin\varphi \cdot d\varphi \cdot d\lambda + \cos\varphi \cdot d\lambda \cdot dh$$

$$dn = \left(\frac{a(1-e^2)}{\chi^3} + h\right) \cdot d\varphi + \frac{3}{2} a \cdot \cos\varphi \cdot \sin\varphi \cdot e^2 \cdot d\varphi^2 + dh \cdot d\varphi + \frac{1}{2}\sin\varphi \cdot \cos\varphi \cdot \left(1 - \frac{3}{2}e^2 \cdot \cos\varphi + \frac{1}{2}e^2 + \frac{h}{a}\right) \cdot d\varphi^2$$

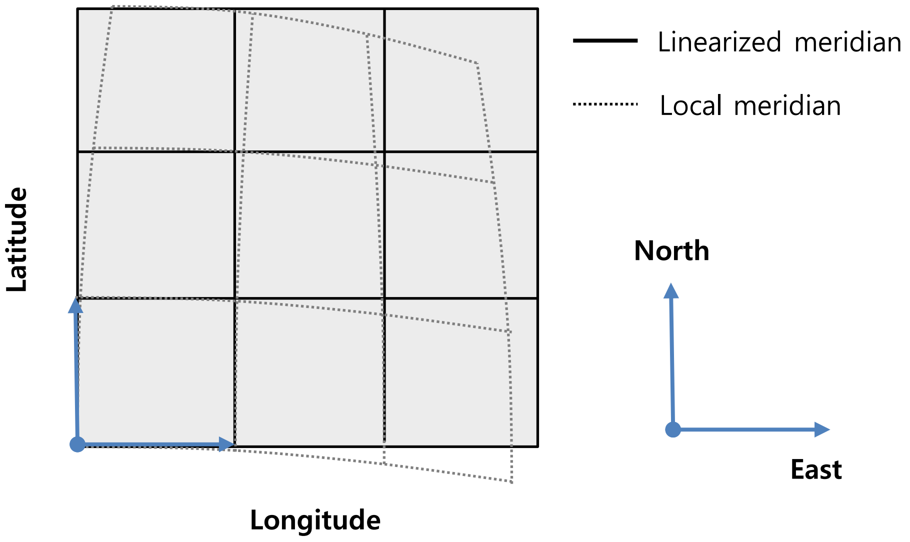
$$du = dh - \frac{1}{2}a \cdot \left(1 - \frac{3}{2}e^2 \cdot \cos\varphi + \frac{1}{2}e^2 + \frac{h}{a}\right) \cdot d\varphi^2 - \frac{1}{2}\left(\frac{a\cos^2\varphi}{\chi} - h\cos^2\varphi\right) \cdot d\lambda^2$$

Numerical estimation

Previous Approaches (2/4)

Disadvantage of conversion via the ECEF coordinate

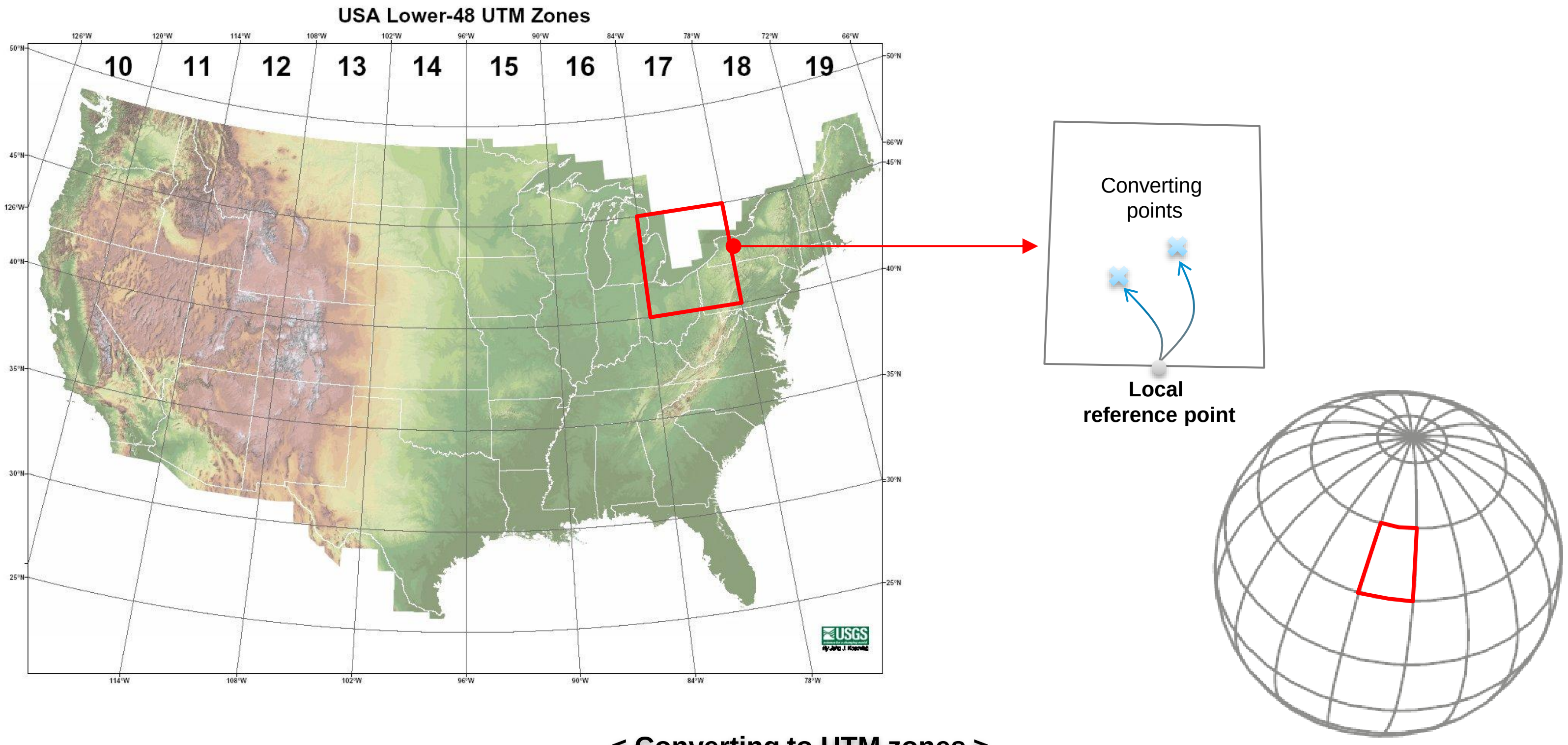
- Complex equation
  - Equations take additional computation burden.
- Linearization error
  - Increasing the error of point which is far from the reference point.



Previous Approaches (3/4)

■ Converting to UTM coordinate

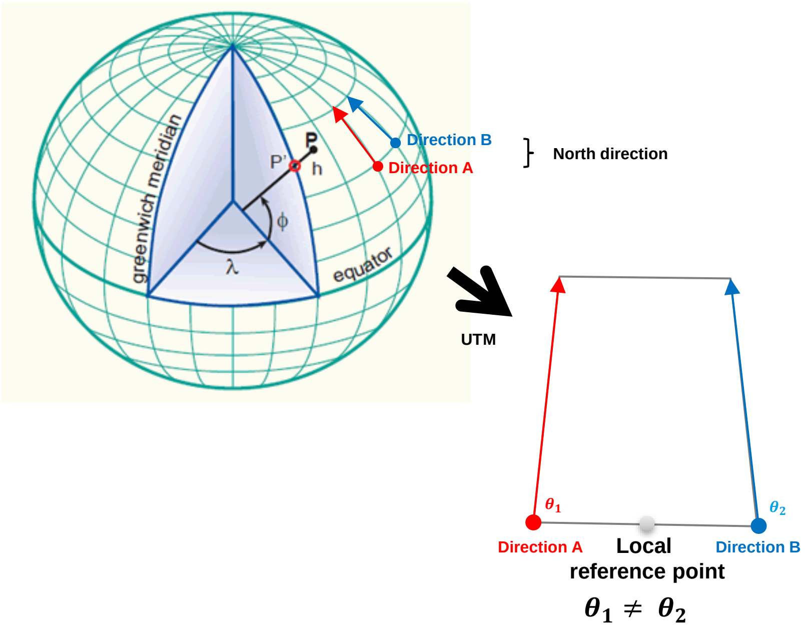
- ▶ UTM (Universal Transverse Mercator) coordinate
  - Conversion on divided zone with fixed local reference point.



< Converting to UTM zones >

Previous Approaches (4/4)

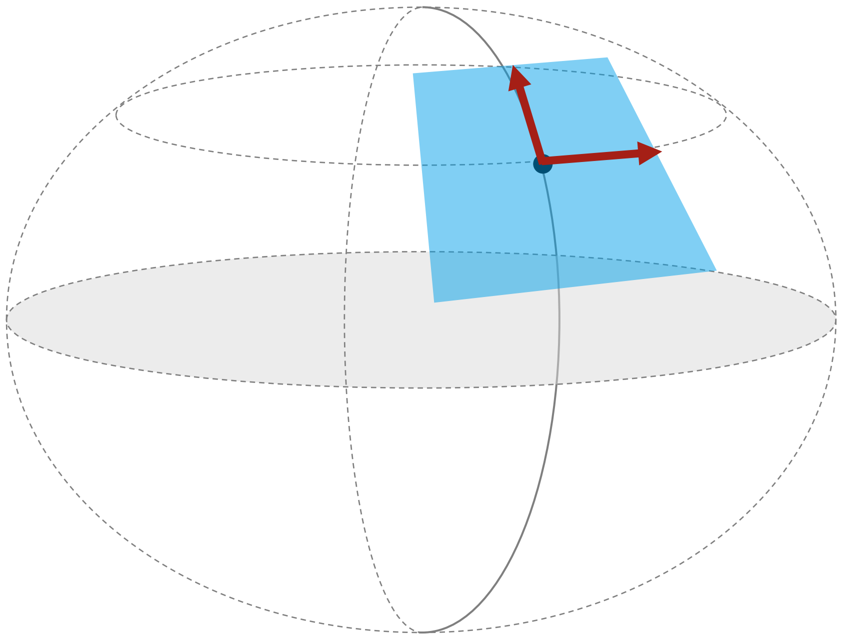
- **Disadvantage of converting to UTM coordinate**
  - Incorrect heading angle information on far point from the reference point.

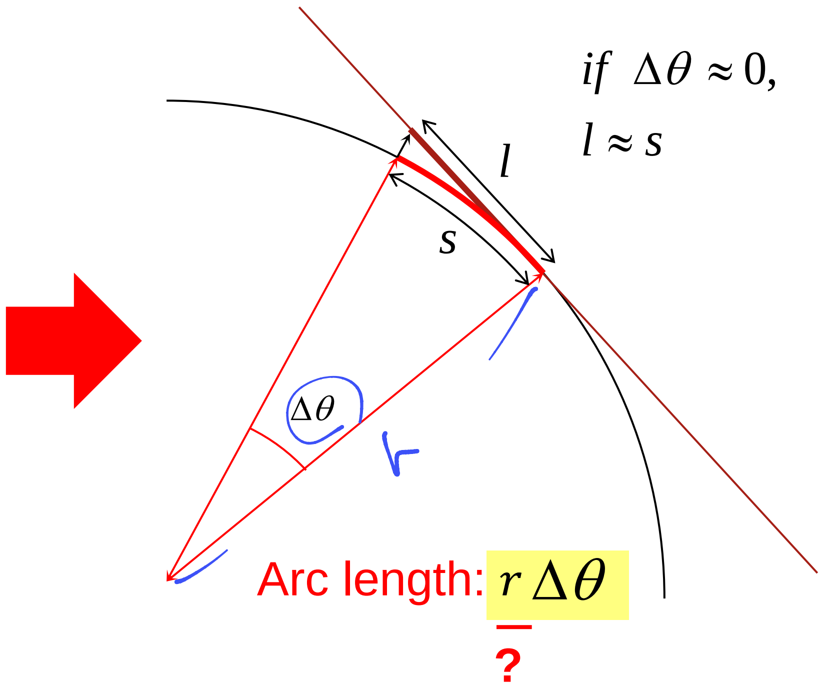


Simplified Coordinate Conversion (1/6)

Analytical approach

- Approximation the line of plane to arc-length in short range





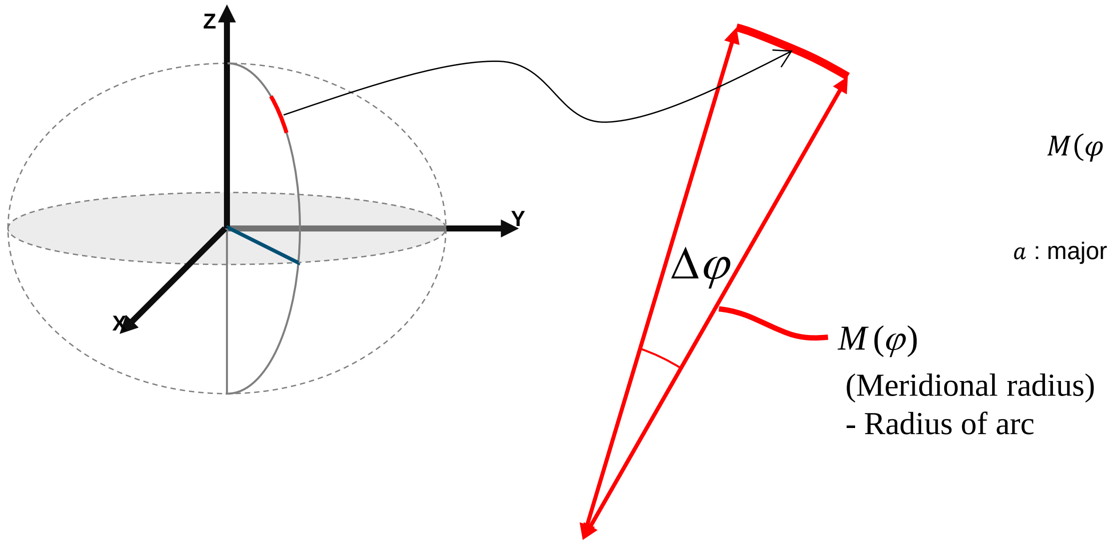
Jo, K., Lee, M., & Sunwoo, M. (2016). Fast GPS-DR Sensor Fusion Framework: Removing the Geodetic Coordinate Conversion Process. *IEEE Transactions on Intelligent Transportation Systems*, *17*(7), 2008–2013.

Simplified Coordinate Conversion (2/6)

Location-dependent radius (I)

Meridional radius

- The radius of arc which along the meridional line (North direction)



$$M(\varphi) = \frac{(ab)^2}{\left((a\cos\varphi)^2 + (b\sin\varphi)^2\right)^{3/2}}$$

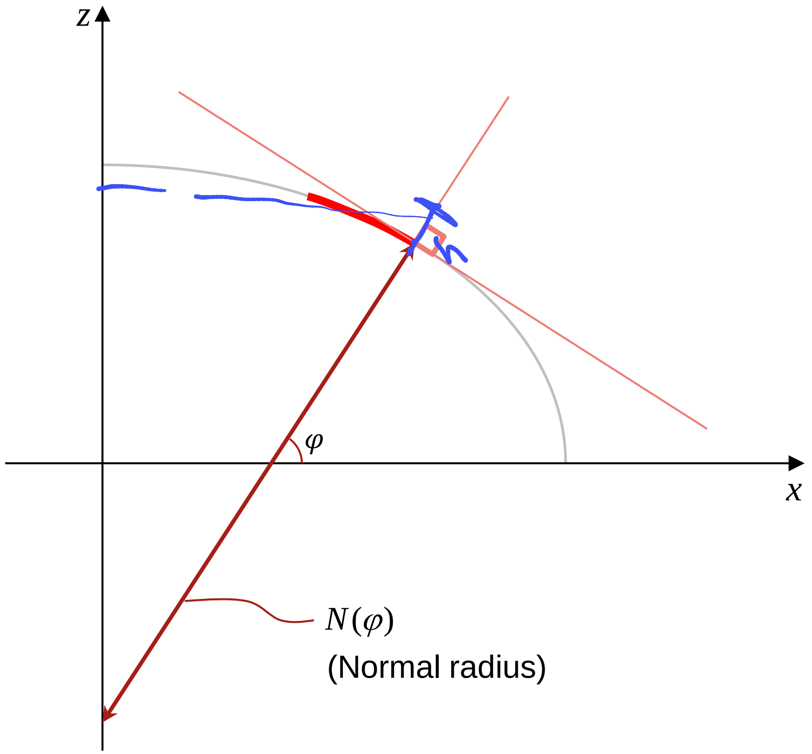
a : major radius of ellipse, b: minor radius of ellipse

Jo, K., Lee, M., & Sunwoo, M. (2016). Fast GPS-DR Sensor Fusion Framework: Removing the Geodetic Coordinate Conversion Process. *IEEE Transactions on Intelligent Transportation Systems*, *17*(7), 2008–2013.

Simplified Coordinate Conversion (3/6)

Location-dependent radius (II)

- Normal radius
  - Radius of normal direction of approximation plane on reference point



$$N(\varphi) = \frac{a^2}{\sqrt{(a\cos\varphi)^2 + (b\sin\varphi)^2}}$$

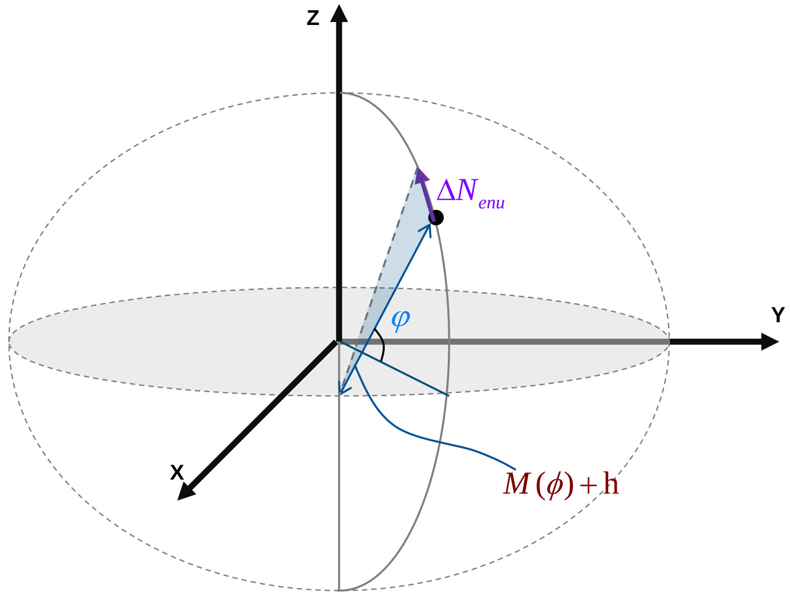
a : major radius of ellipse, b: minor radius of ellipse

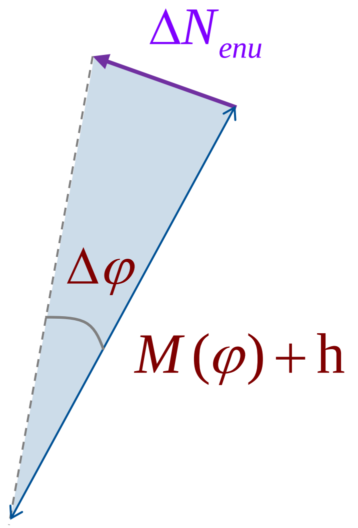
Jo, K., Lee, M., & Sunwoo, M. (2016). Fast GPS-DR Sensor Fusion Framework: Removing the Geodetic Coordinate Conversion Process. *IEEE Transactions on Intelligent Transportation Systems*, *17*(7), 2008–2013.

Simplified Coordinate Conversion (4/6)

North direction length

- Arc-length derived by meridional radius, height and latitude





GPS
Lat
φ
Ref Lat
$\Delta\varphi$
h

$$\Delta N = (M(\varphi)+\mathrm{h})\cdot\Delta\varphi$$

$$\Delta\varphi = \frac{\Delta N}{M(\varphi)+\mathrm{h}}$$

Jo, K., Lee, M., & Sunwoo, M. (2016). Fast GPS-DR Sensor Fusion Framework: Removing the Geodetic Coordinate Conversion Process. *IEEE Transactions on Intelligent Transportation Systems*, *17*(7), 2008–2013.

Simplified Coordinate Conversion (5/6)

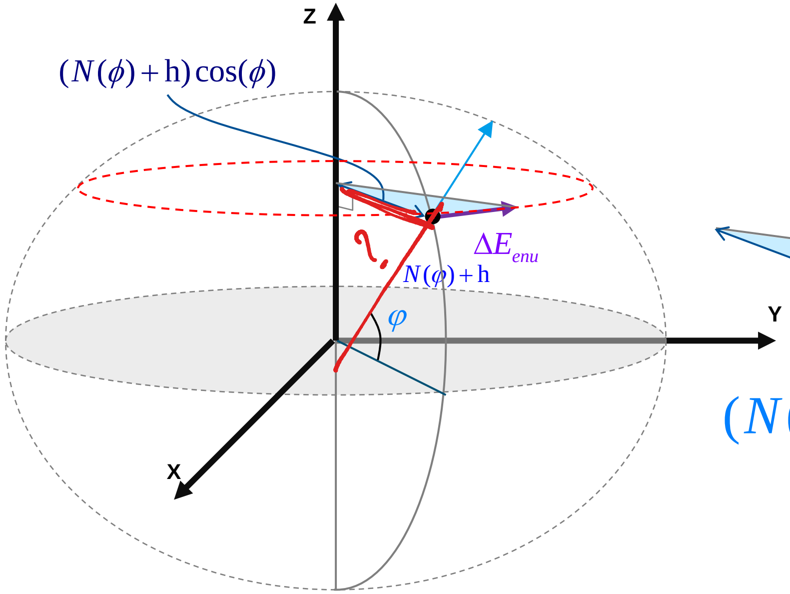
- **East direction length**
  - Arc-length derived by normal radius, height and latitude

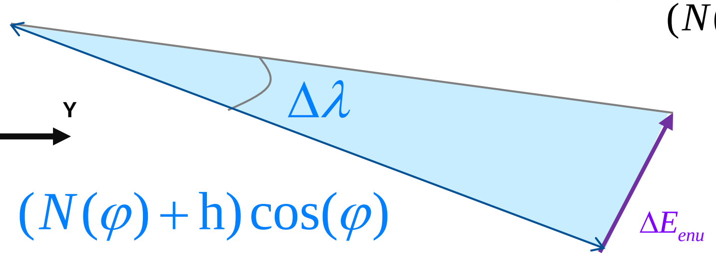
Gps → [Lat, Long, h]

Ref → [Lat, Long]

Δφ

Δλ





$$\Delta E = (N(\varphi)+\mathrm{h})\cdot\cos\varphi\cdot\Delta\lambda$$

$$\Delta\lambda = \frac{\Delta E}{(N(\varphi)+\mathrm{h})\cdot\cos\varphi}$$

Jo, K., Lee, M., & Sunwoo, M. (2016). Fast GPS-DR Sensor Fusion Framework: Removing the Geodetic Coordinate Conversion Process. *IEEE Transactions on Intelligent Transportation Systems*, *17*(7), 2008–2013.

Simplified Coordinate Conversion (6/6)

Assuming to constant

- Very small changed Latitude in short range
- Calculating terms of latitude as constants

$$\frac{1}{N(\varphi_m)\cdot\cos\varphi_m} \approx \frac{1}{N(\varphi_n)\cdot\cos\varphi_n}$$

$$\frac{1}{M(\varphi_m)} \approx \frac{1}{M(\varphi_n)}$$

When, $\varphi_m - \varphi_n \approx 0$

$$\kappa_{\lambda,k} = \frac{1}{N(\varphi^+_{k-1})\cdot\cos\varphi^+_{k-1}}$$

$$\kappa_{\varphi,k} = \frac{1}{M(\varphi^+_{k-1})}$$

$$\Delta\lambda = \kappa_\lambda \cdot \Delta E$$

$$\Delta\varphi = \kappa_\varphi \cdot \Delta N$$

$$h_{geod} = h_{enu}$$

Jo, K., Lee, M., & Sunwoo, M. (2016). Fast GPS-DR Sensor Fusion Framework: Removing the Geodetic Coordinate Conversion Process. *IEEE Transactions on Intelligent Transportation Systems*, *17*(7), 2008–2013.

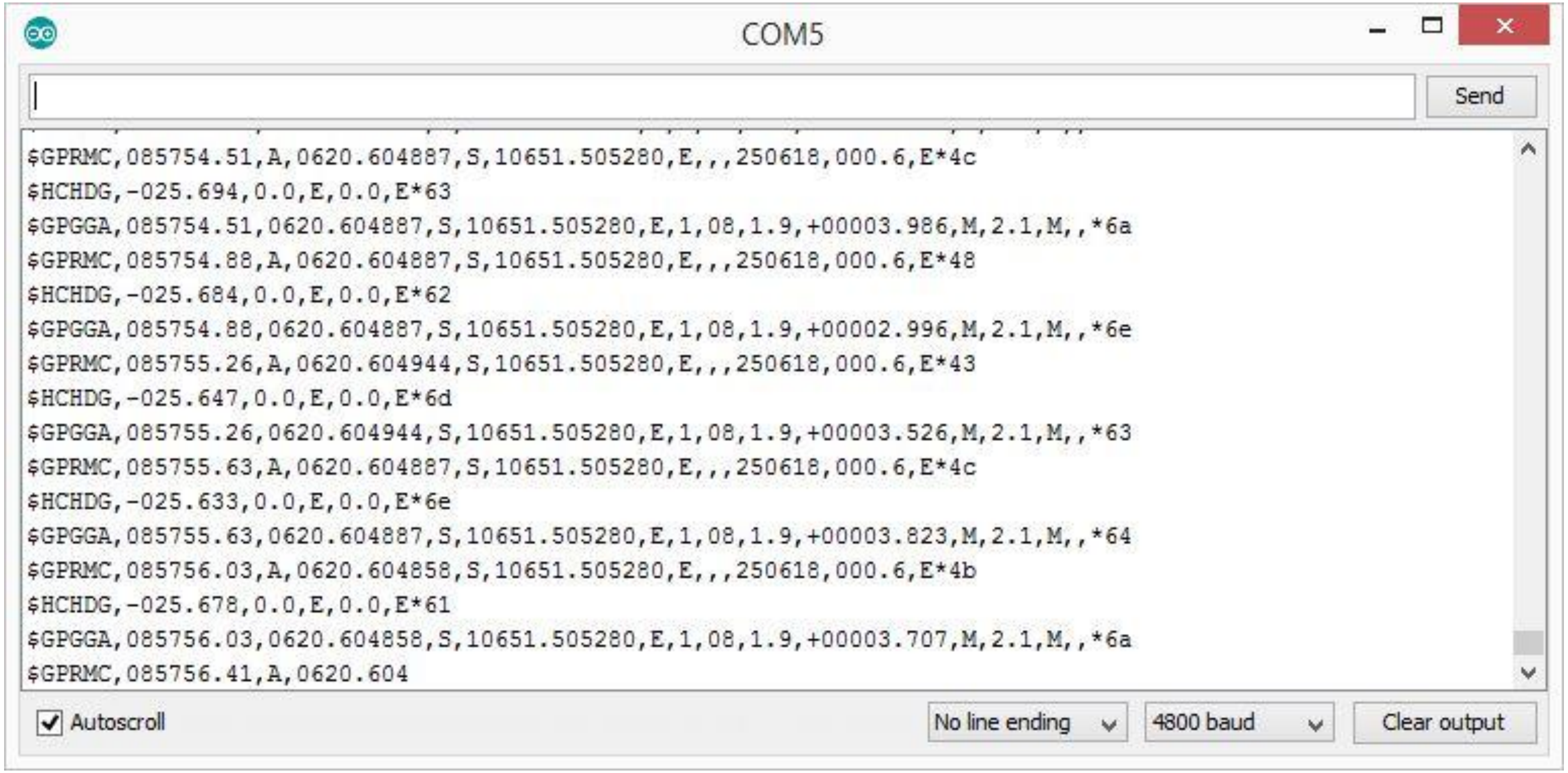
NMEA interface

NMEA 0183

- **The National Marine Electronics Association (NMEA) has developed a specification that defines the interface between various pieces of marine electronic equipment.**
- **The NMEA 0183 standard uses a simple ASCII, serial communications protocol that defines how data are transmitted in a "sentence" from one "talker" to multiple "listeners" at a time.**
- **NMEA consists of sentences, the first word of which, called a data type, defines the interpretation of the rest of the sentence.**
- **Various NMEA sentences**
  - AAM - Waypoint Arrival Alarm
  - ALM - Almanac data
  - APA - Auto Pilot A sentence
  - APB - Auto Pilot B sentence
  - BOD - Bearing Origin to Destination
  - BWC - Bearing using Great Circle route
  - DTM - Datum being used.
  - **GGA - Fix information**
  - GLL - Lat/Lon data
  - GRS - GPS Range Residuals
  - GSA - Overall Satellite data
  - GST - GPS Pseudorange Noise Statistics
  - GSV - Detailed Satellite data
  - MSK - send control for a beacon receiver
  - MSS - Beacon receiver status information.
  - RMA - recommended Loran data
  - RMB - recommended navigation data for gps
  - **RMC - recommended minimum data for gps**
  - RTE - route message
  - TRF - Transit Fix Data
  - STN - Multiple Data ID
  - VBW - dual Ground / Water Spped
  - VTG - Vector track an Speed over the Ground
  - WCV - Waypoint closure velocity (Velocity Made Good)
  - WPL - Waypoint Location information
  - XTC - cross track error
  - XTE - measured cross track error
  - ZTG - Zulu (UTC) time and time to go (to destination)
  - ZDA - Date and Time

NMEA 0183

Samples



NMEA 0183

GGA - essential fix data which provide 3D location and accuracy data.

- $GPGGA,134658.00,5106.9792,N,11402.3003,W,2,09,1.0,1048.47,M,-16.27,M,08,AAAA*60

Field	Structure	Description	Symbol	Example
1	$GPGGA	Log header. See Messages for more information.		$GPGGA
2	utc	UTC time status of position (hours/minutes/seconds/ decimal seconds)	hhmmss.ss	202134.00
3	lat	Latitude (DDmm.mm)	llll.ll	5106.9847
4	lat dir	Latitude direction (N = North, S = South)	a	N
5	lon	Longitude (DDDmm.mm)	yyyyy.yy	11402.2986
6	lon dir	Longitude direction (E = East, W = West)	a	W
7	quality	0 = invalid 1 = GPS fix (SPS) 2 = DGPS fix 3 = PPS fix 4 = Real Time Kinematic 5 = Float RTK 6 = estimated (dead reckoning) (2.3 feature) 7 = Manual input mode 8 = Simulation mode	x	1
8	# sats	Number of satellites in use. May be different to the number in view	xx	10
9	hdop	Horizontal dilution of precision	x.x	1.0
10	alt	Antenna altitude above/below mean sea level	x.x	1062.22
11	a-units	Units of antenna altitude (M = metres)	M	M
12	undulation	Undulation - the relationship between the geoid and the WGS84 ellipsoid	x.x	-16.271
13	u-units	Units of undulation (M = metres)	M	M
14	age	Age of correction data (in seconds) The maximum age reported here is limited to 99 seconds.	xx	(empty when no differential data is present)
15	stn ID	Differential base station ID	xxxx	(empty when no differential data is present)
16	*xx	Check sum	*hh	*48
17	[CR][LF]	Sentence terminator		[CR][LF]

NMEA 0183

- **RMC** contains time, date, position, track made good and speed data provided by the GPS navigation receiver. RMC is the recommended minimum navigation data.
  - $GPRMC,144326.00,A,5107.0017737,N,11402.3291611,W,0.080,323.3,210307,0.0,E,A*20

Field	Structure	Description	Symbol	Example
1	$GPRMC	Log header. See Messages for more information.		$GPRMC
2	utc	UTC of position	hhmmss.ss	144326.00
3	pos status	Position status (A = data valid, V = data invalid)	A	A
4	lat	Latitude (DDmm.mm)	llll.ll	5107.0017737
5	lat dir	Latitude direction: (N = North, S = South)	a	N
6	lon	Longitude (DDDmm.mm)	yyyyy.yy	11402.3291611
7	lon dir	Longitude direction: (E = East, W = West)	a	W
8	speed Kn	Speed over ground, knots	x.x	0.080
9	track true	Track made good, degrees True	x.x	323.3
10	date	Date: dd/mm/yy	xxxxxx	210307
11	mag var	Magnetic variation, degrees Note that this field is the actual magnetic variation and will always be positive. The direction of the magnetic variation is always positive.	x.x	0.0
12	var dir	Magnetic variation direction E/W Easterly variation (E) subtracts from True course. Westerly variation (W) adds to True course.	a	E
13	mode ind	Positioning system mode indicator, see Table: NMEA Positioning System Mode Indicator	a	A
14	*xx	Check sum	*hh	*20
15	[CR][LF]	Sentence terminator		[CR][LF]

THANK YOU
FOR YOUR ATTENTION