Session 5.1

Tuesday, 22nd June | 15.00 – 16.30

SMART SURVEYORS FOR LAND AND WATER MANAGEMENT
CHALLENGES IN A NEW REALITY

UTM UNIVERSITI TEKNOLOGI MALAYSIA

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e WORKING WEEK 2021
20-25 JUNE

Geodetic Datum in Hydrographic Survey Practices: WGS84 versus ITRF (Paper ID: 11261)

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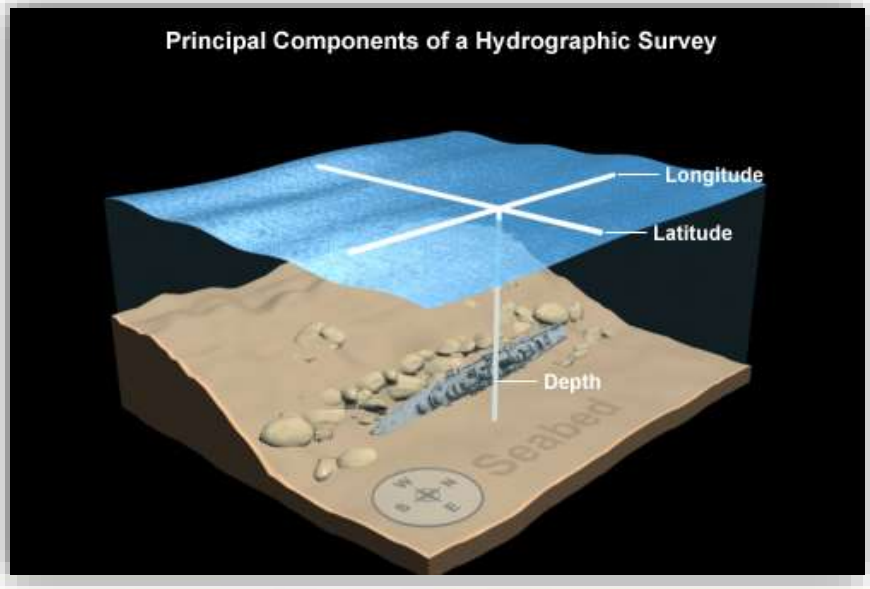
Evolution of Hydrographic Positioning

What is Hydrography? IHO Definition

The branch of applied science which deals with the **measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers**, as well as with **the prediction of their change over time**, for the primary purpose of **safety of navigation** and in support of all other marine activities, including **economic development, security and defense, scientific research, and environmental protection**.



Four major components of Hydrographic Survey

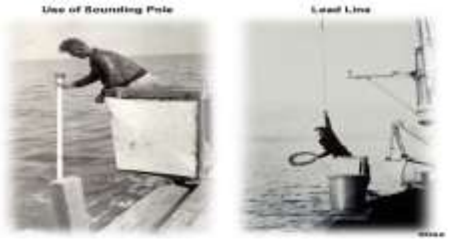
1. Positioning	*refers to the **location** of the survey data with respect to latitude and longitude.*
2. Water Depth	*Measures from a **vertical reference surface** or datum to the seafloor.*
3. Features	*refers to as **targets** which may be hazards to navigation (i.e., shoals, reefs and other features).*
4. Seafloor Characteristics	*refers primarily to the **bottom type** (i.e., mud, sand, bedrock, coral reef).*

Evolution of Hydrographic Positioning

Vertical & Horizontal Controls

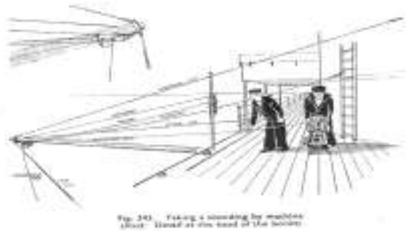
- **Main objective Hydrographic Survey**
  - *To **determine the water depth** at particular locations.*
- **Soundings** are the **measurement of water depth** and the **position of soundings** must be known.
  - Requires the **determination of latitude and longitude** with respect to the desired horizontal datum.
  - The **position accuracy** must meet **IHO S-44 standards** applicable to the survey.
- A Vertical Control is needed for soundings as well as Horizontal Control is needed to locate the soundings.

Evolution of Hydrographic Methods

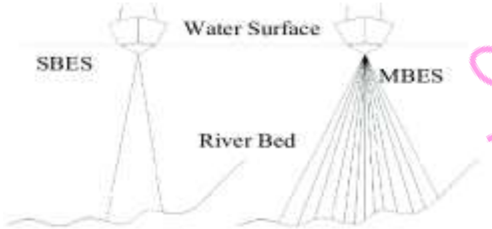


Sounding Pole & Lead Line

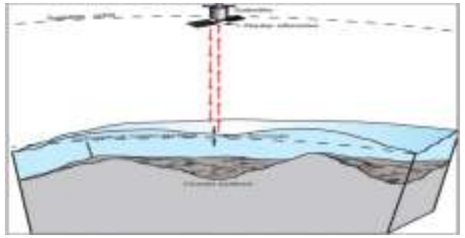
Wire-drag



Machine Sounding



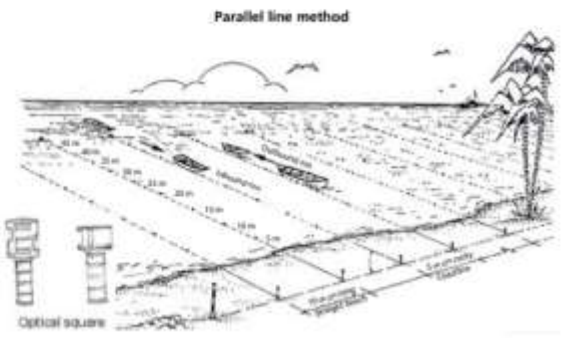
Acoustic Sounding (SBES & MBES)

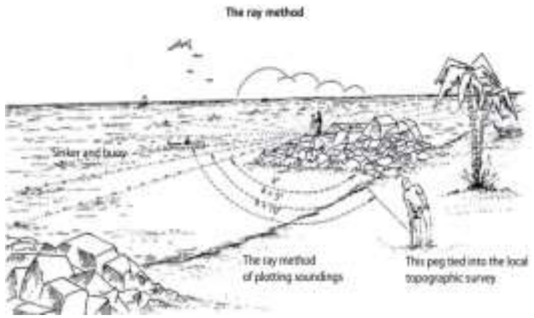


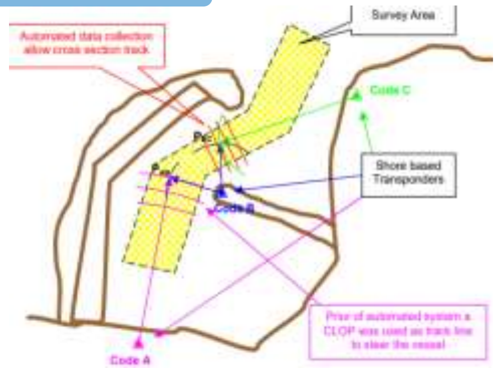
Satellite-Derived Bathymetry (SDB)

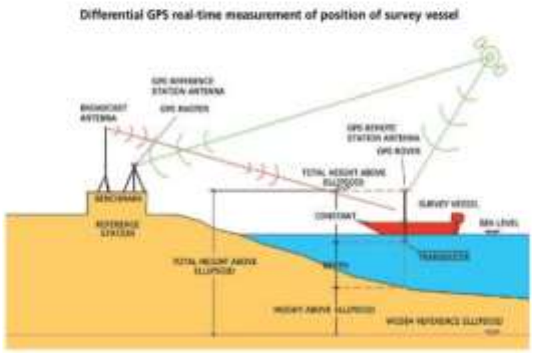
Evolution of Hydrographic Positioning

Hydrographic Position Fixing









Parallel Line Method

- The **hand-held optical square** in conjunction with a **float line method**.
- Setting out a straight baseline along the shore with **a ranging rod** placed at either end.
- At every **5/10 m**, a steel peg is driven into the ground, a buoy is dropped offshore at right angles to each peg.

The Ray / Triangulation Method

- The **single theodolite**, in conjunction with a **float line** (**Ray Method**) or;
- **Twin theodolite intersection** (**triangulation method**), is the second most basic method of fixing positions offshore.
- Often used to **position vessels on near-shore** projects.

Electronic Positioning System (EPS) Method

- Replaced triangulation method by using **range-range** positioning techniques.
- Using **trilateration concept** in determining the coordinate by intersection.
- **Still in use** in those areas where **poor GPS signal coverage**.

Global Navigation Satellite System (GNSS)

- **Continuous, all-weather, worldwide**, satellite-based electronic positioning system.
- **Differential GNSS** – the primary survey reference for hydrographic positioning activities .
- Can produce **real-time positions** of a moving vessel.

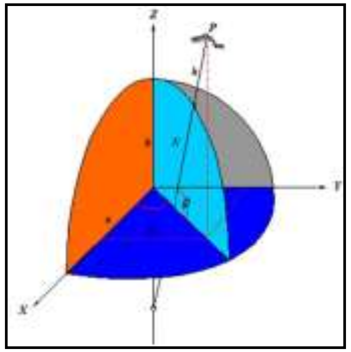
Geodetic Datum

Definition

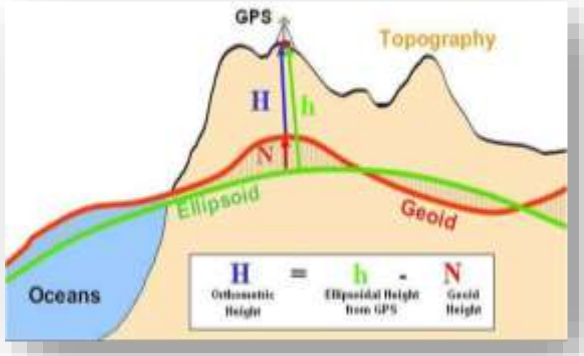
- A **coordinate system** with a **reference surface** that serves to provide **known locations** to begin surveys and create maps.
- Geodesists and surveyors use **datum** to create **starting or reference points** for any work requiring accurate coordinates that are consistent with one another.

Types of Geodetic Datum

Horizontal Datum



Vertical Datum

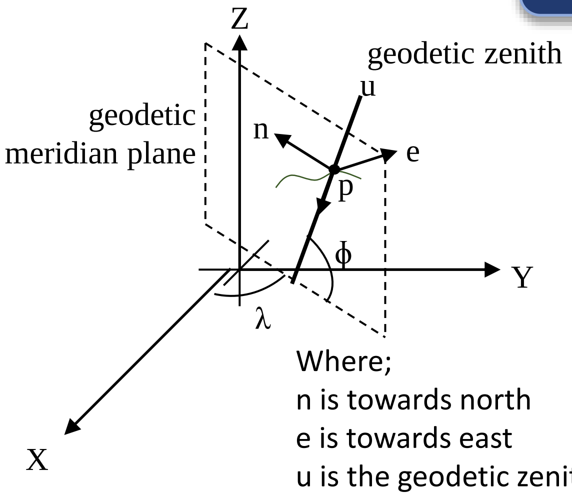


Note:

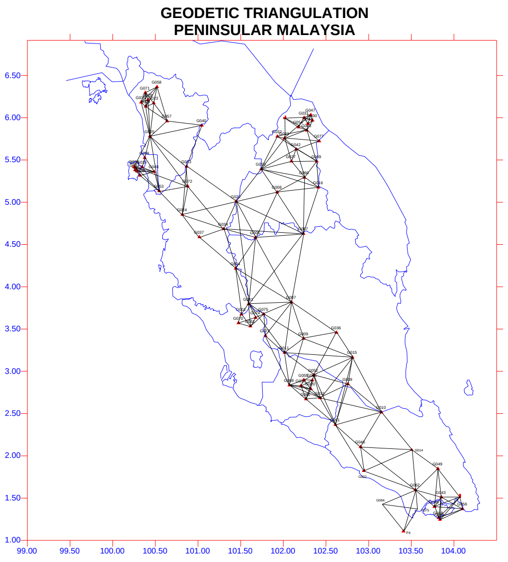
*Prior to the advent of space based measurements, **geodetic datums were locally defined** and were sufficient for surveyors working in that local area. **Their origins differed from the geo-centre** by hundreds of metres.*

Geodetic Datum

Definition

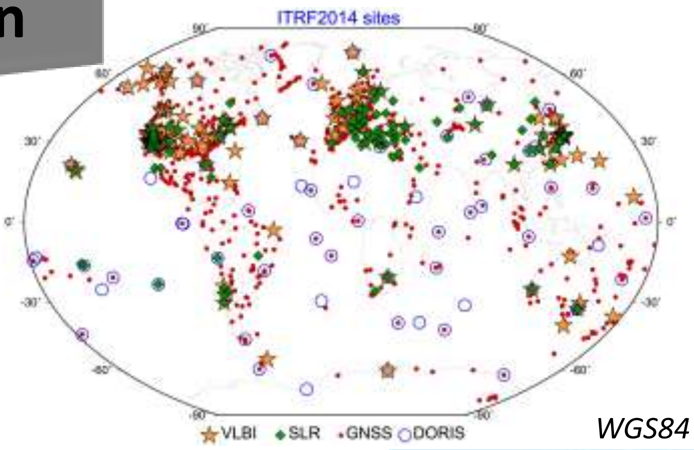


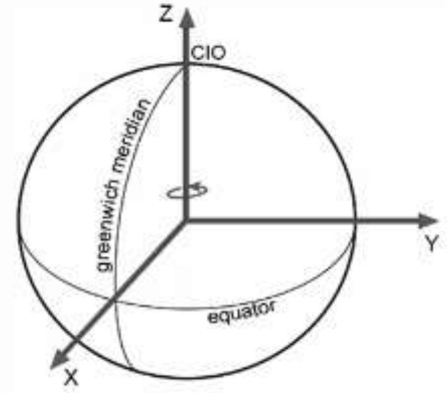
Where;
n is towards north
e is towards east
u is the geodetic zenith



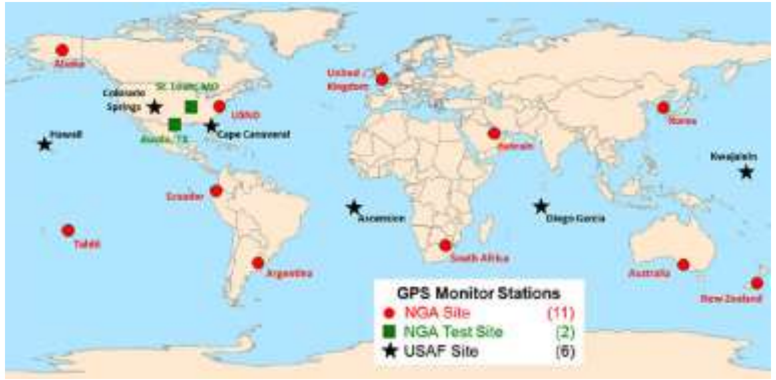
Classical Topocentric Datum

Modern Geocentric Datum



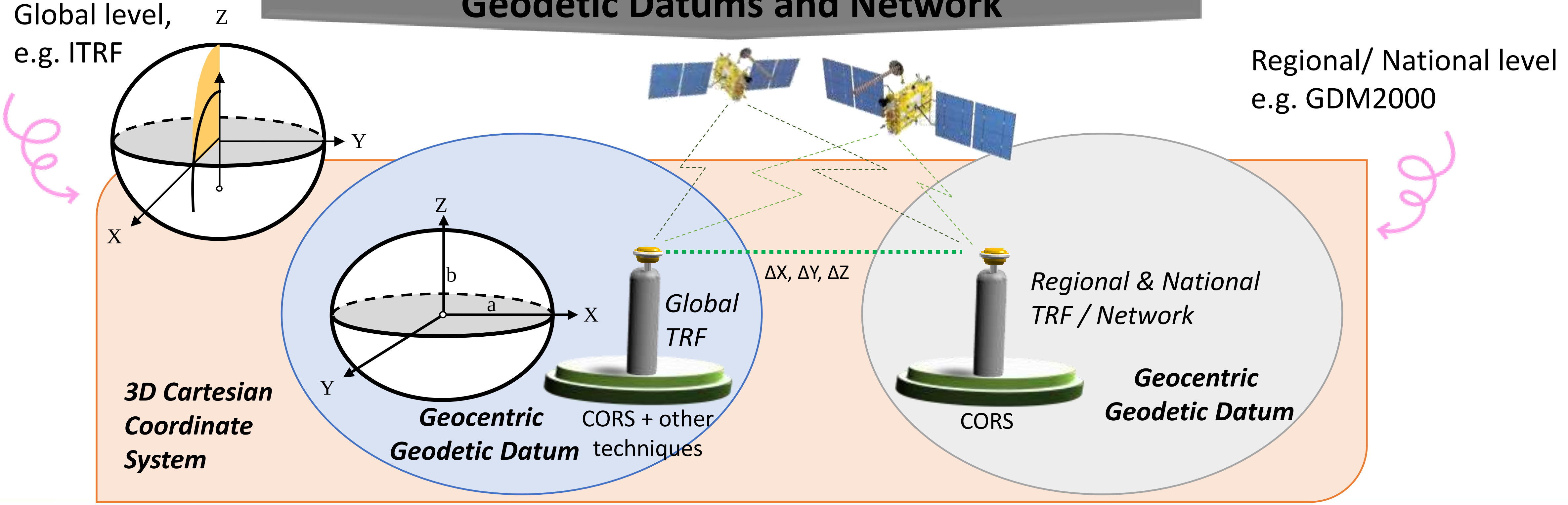


WGS84 (G1762) Reference Frame Stations



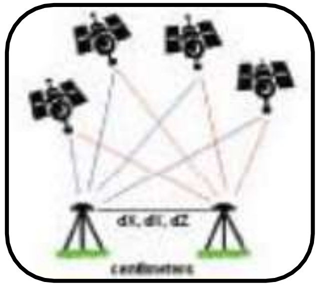
Geodetic Datum

Relationship: Modern (3D) Coordinate Systems, Geodetic Datums and Network



GNSS Positioning Modes

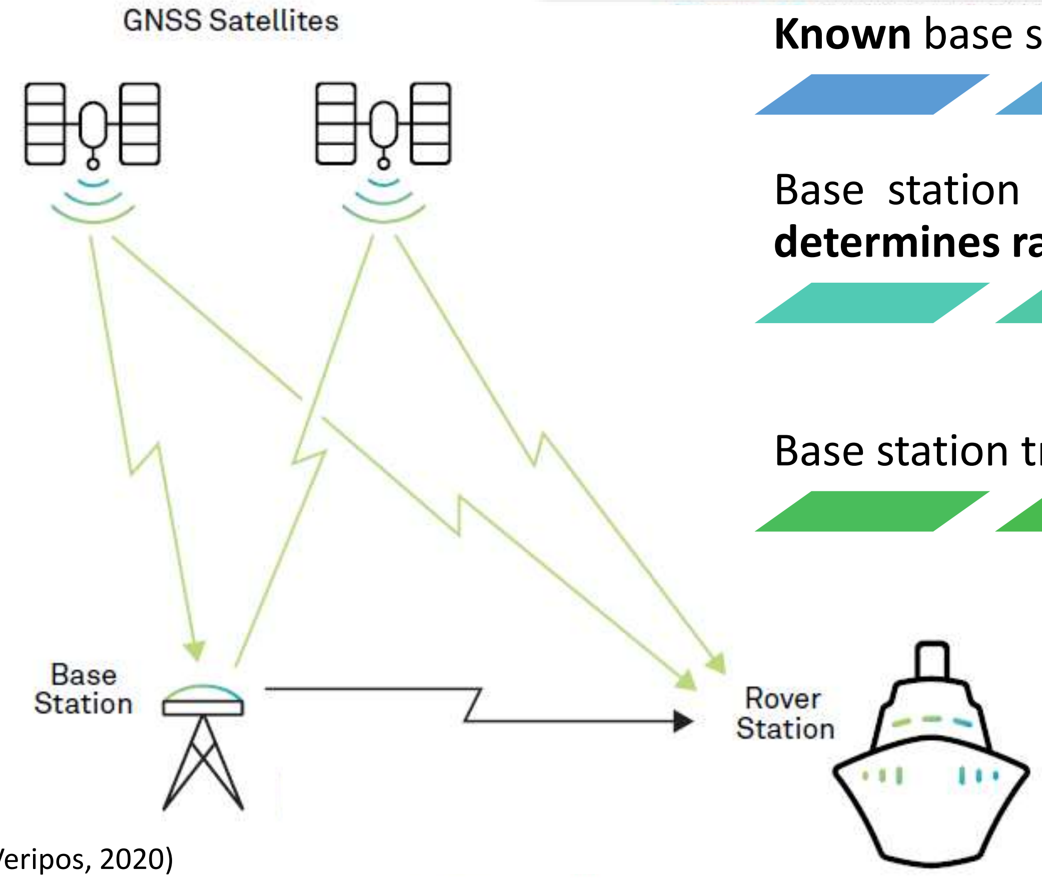
- GNSS POSITIONING
  - ABSOLUTE
    - Post-processed PPP
    - Real-time PPP
  - RELATIVE
    - DGNSS
    - SBAS
    - RTK



Involve a **single receiver** and sufficiently accurate for precise positioning requirements using carrier phase observation.

Require **at least 2 receivers** and can provide the accuracies required for basic positioning.

GNSS Positioning Mode: DGNSS



(Veripos, 2020)

Known base station (with high degree accuracy).

Base station (beacon) **receives signals**, **calculates pseudoranges** to satellites, and **determines range errors**.

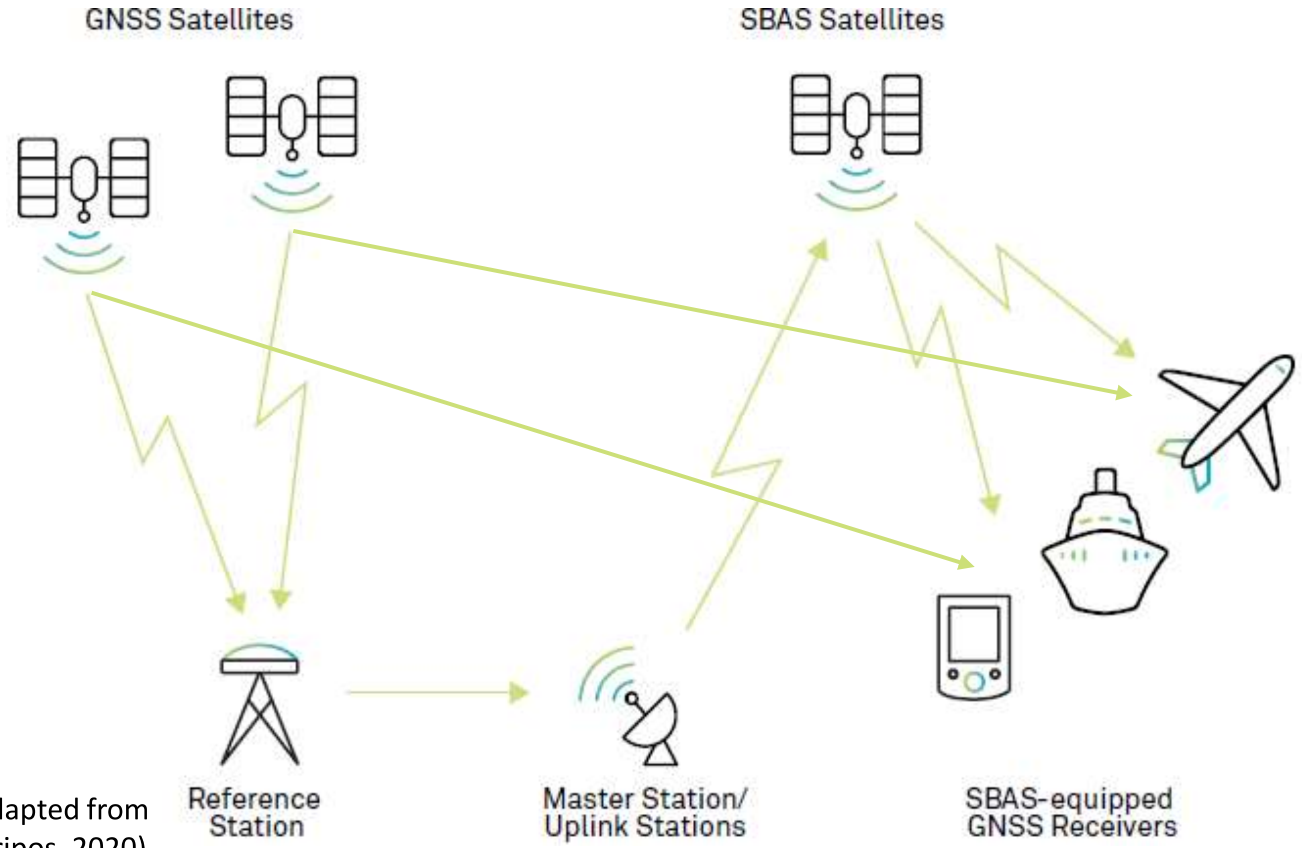
Base station transmits **range corrections** to rover (i.e. ,via **radio link**).

Rover station **receive signals**, **calculate pseudoranges**, and **apply corrections**.

Corrected ranges are used to **determine position**.

GNSS Positioning Mode: SBAS

- SBAS provides **differential correction** and **satellite integrity monitoring** to receiver via **VHF radio link**.
- SBAS consists of **GNSS antennas** at known location, a **central control system**, and a **VHF radio transmitter**.
- SBAS is also synonymous with **WADGNSS**, wide-area DGNSS.

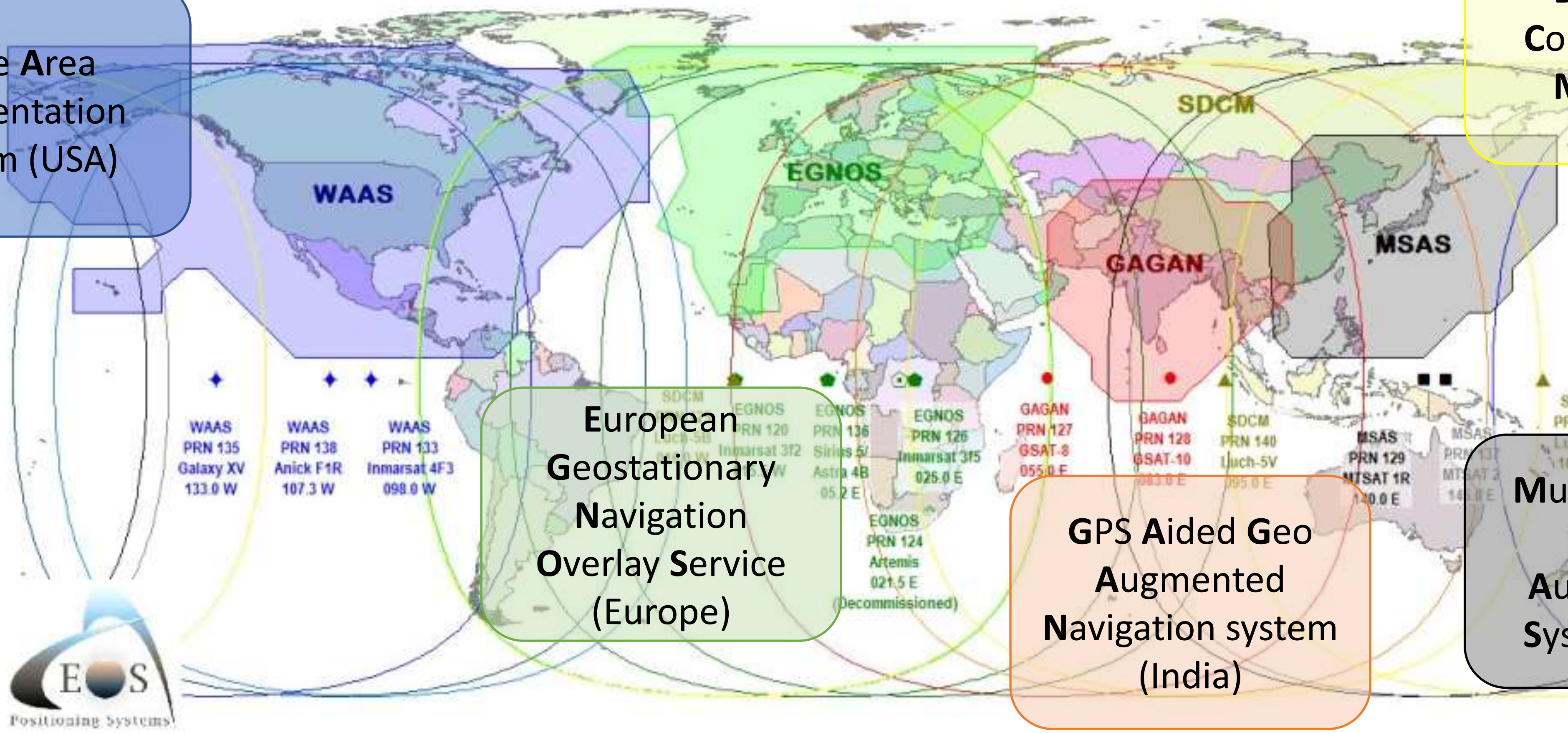


(Adapted from Veripos, 2020)

GNSS Positioning Mode: SBAS

Wide **A**rea **A**ugmentation **S**ystem (USA)

System for **D**ifferential **C**orrection and **M**onitoring (Russia)



European **G**eostationary **N**avigation **O**verlay **S**ervice (Europe)

GPS **A**ided **G**eo **A**ugmented **N**avigation system (India)

Multi-functional **S**atellite **A**ugmentation **S**ystem (Japan)

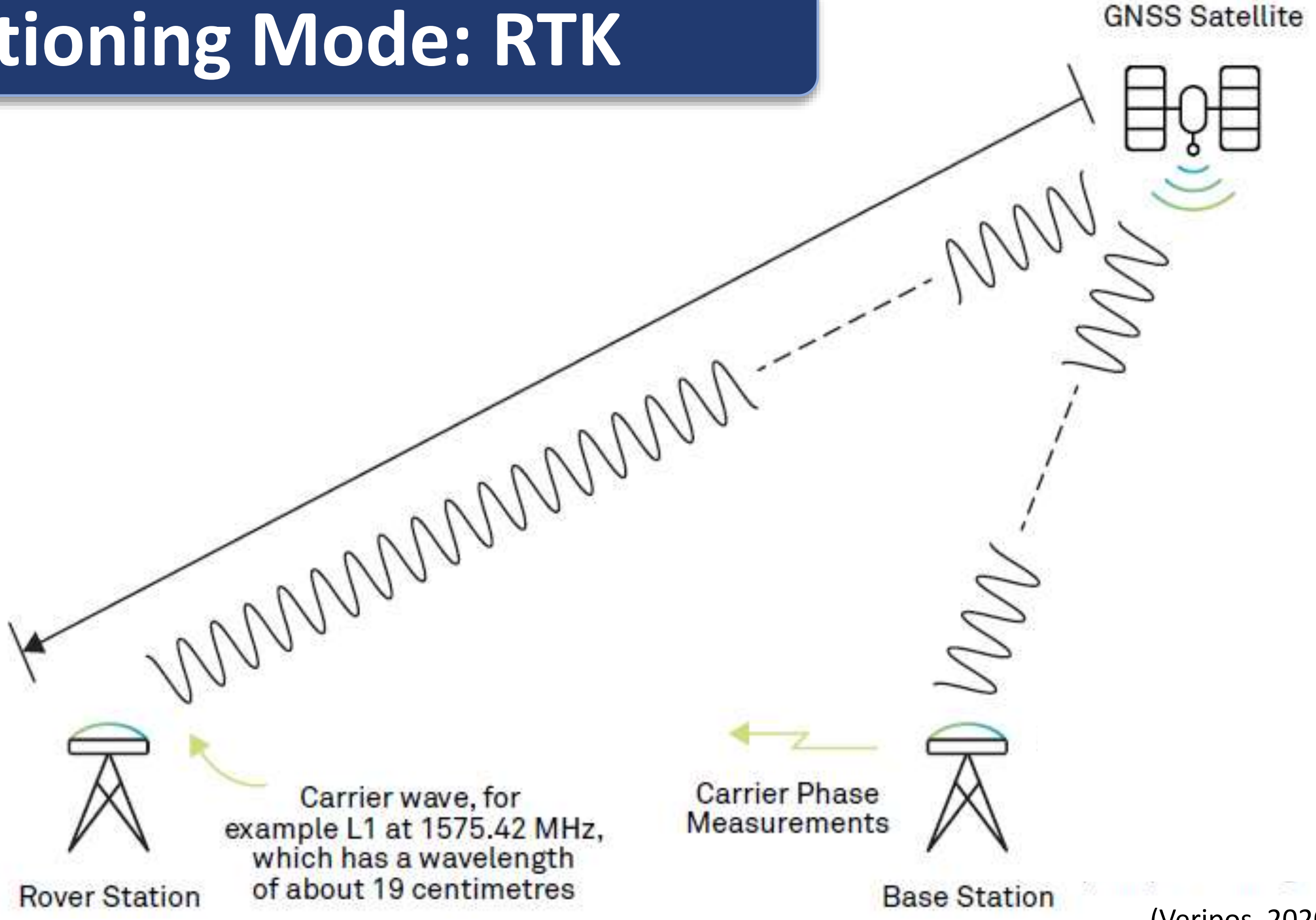
EOS Positioning Systems

GNSS Positioning Mode: RTK

Similar concept with **DGNSS** except for **carrier-based** ranging.

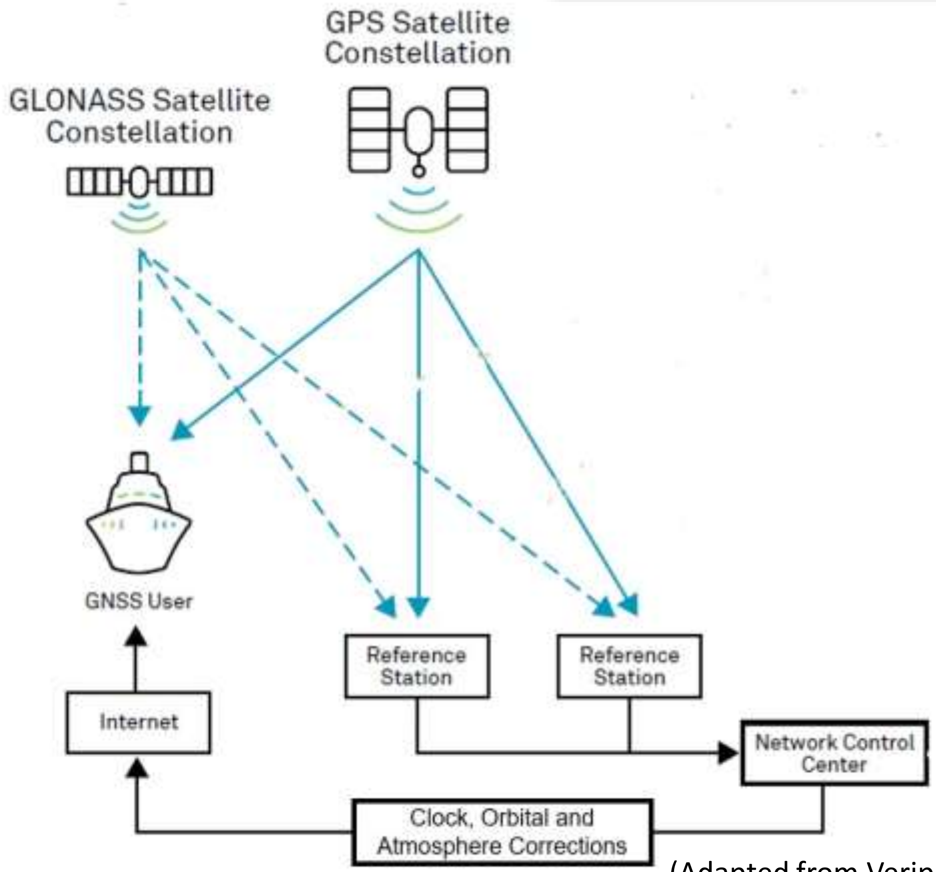
The achievable **accuracy** of a rover is **distance-dependent** (baseline length between rover and base station).

To achieve the best accuracy, the preferable **baseline** must be **less than 40 km**.



(Veripos, 2020)

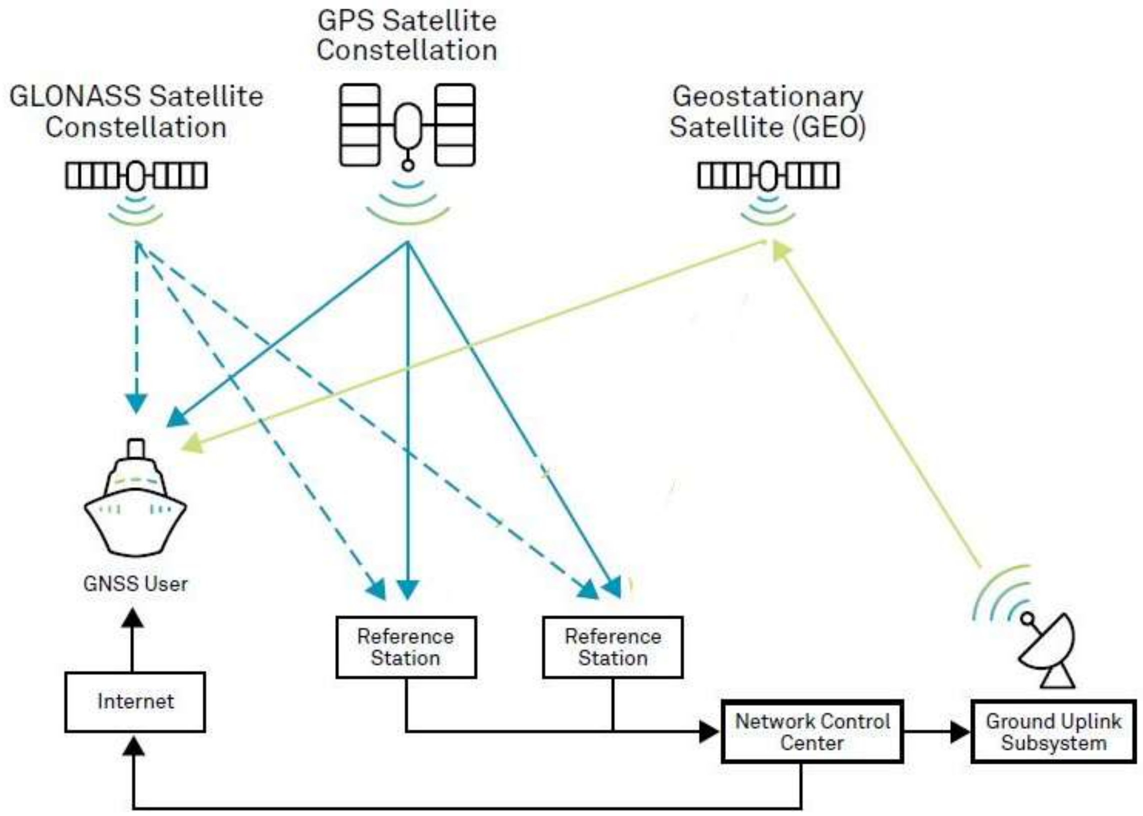
GNSS Positioning Mode: Post-processed PPP



(Adapted from Veripos, 2020)

- Post-processed PPP **solution** depends on the **satellite clock, orbit, and atmospheric corrections**, generated from the reference stations.
- The generated corrections are used by the receiver **without base station.**
- The achievable **accuracy** (cm level) depends on the **quality of the corrections**.
- Post-processed PPP system involves **corrections from the service provider.**

GNSS Positioning Mode: Real-time PPP



(Veripos, 2020)

- Real-time PPP **solution** depends on the **satellite clock, orbit and atmospheric corrections**, generated from the reference stations.
- The generated corrections are used by the receiver **without base station.**
- The achievable **accuracy** (decimetre level) and the **convergence time** depends on the **quality of the correction services**.
- Real-time PPP systems typically **charge a fee** to access the corrections.

GNSS Positioning Mode: Real-time PPP Correction Service Providers

Providers	Correction Services	Observation Used	Horizontal Accuracy
VERIPOS (https://veripos.com/)	Apex	GPS	< 5 cm (95%)
	Apex 2	GPS GLONASS	< 5 cm (95%)
	Apex 5	GPS, GLONASS, BeiDou, Galileo, QZSS	< 4 cm (95%)
	Ultra	GPS	< 10 cm (95%)
	Ultra 2	GPS GLONASS	< 10 cm (95%)

GNSS Positioning Mode: Real-time PPP Correction Service Providers

Providers	Correction Services	Observation Used	Horizontal Accuracy	Convergence Time
Hemisphere Atlas (https://www.hemispheregnss.com/)	Atlas H10	GPS GLONASS Galileo BeiDou	4 cm (RMS)	12 – 20 min
			8 cm (95%)	
	Atlas H30		15 cm (RMS)	4 – 5 min
			30 cm (95%)	
	Atlas Basic		30 cm (RMS)	
			50 cm (95%)	

GNSS Positioning Mode: Real-time PPP Correction Service Providers

Providers	Correction Services	Observation Used	Horizontal Accuracy	Convergence Time
Trimble (https://www.trimble.com/)	CenterPoint RTX	GPS GLONASS BeiDou Galileo QZSS	< 2 cm (RMS)	Fast: < 1 min Standard: < 15 min
			< 2.5 cm (95%)	Fast: < 2 min Standard: < 20 min
	FieldPoint RTX		10 cm (RMS) 20 cm (95%)	Fast: < 1 min Standard: < 15 min
	RangePoint RTX		30 cm (RMS) 50 cm (95%)	< 5 min
	ViewPoint RTX		< 50 cm (RMS) 100 cm (95%)	< 5 min

GNSS Positioning Mode: Real-time PPP Correction Service Providers

Provider	Correction Services	Observation Used	Horizontal Accuracy	Convergence Time
Fugro (https://www.fugro.com/)	Starfix.G4	GPS, GLONASS, Galileo, BeiDou	10 cm (95%)	20 min
	Starfix.G2	GPS, GLONASS	10 cm (95%)	
	Starfix.G2+	GPS, GLONASS	3 cm (95%)	
	Starfix.XP2	GPS, GLONASS	10 cm (95%)	
	Starfix.HP	GPS	Up to 1000 km: 10 (95%)	
	Starfix.L1	GPS	Up to 500 km: < 1.5 m (95%)	

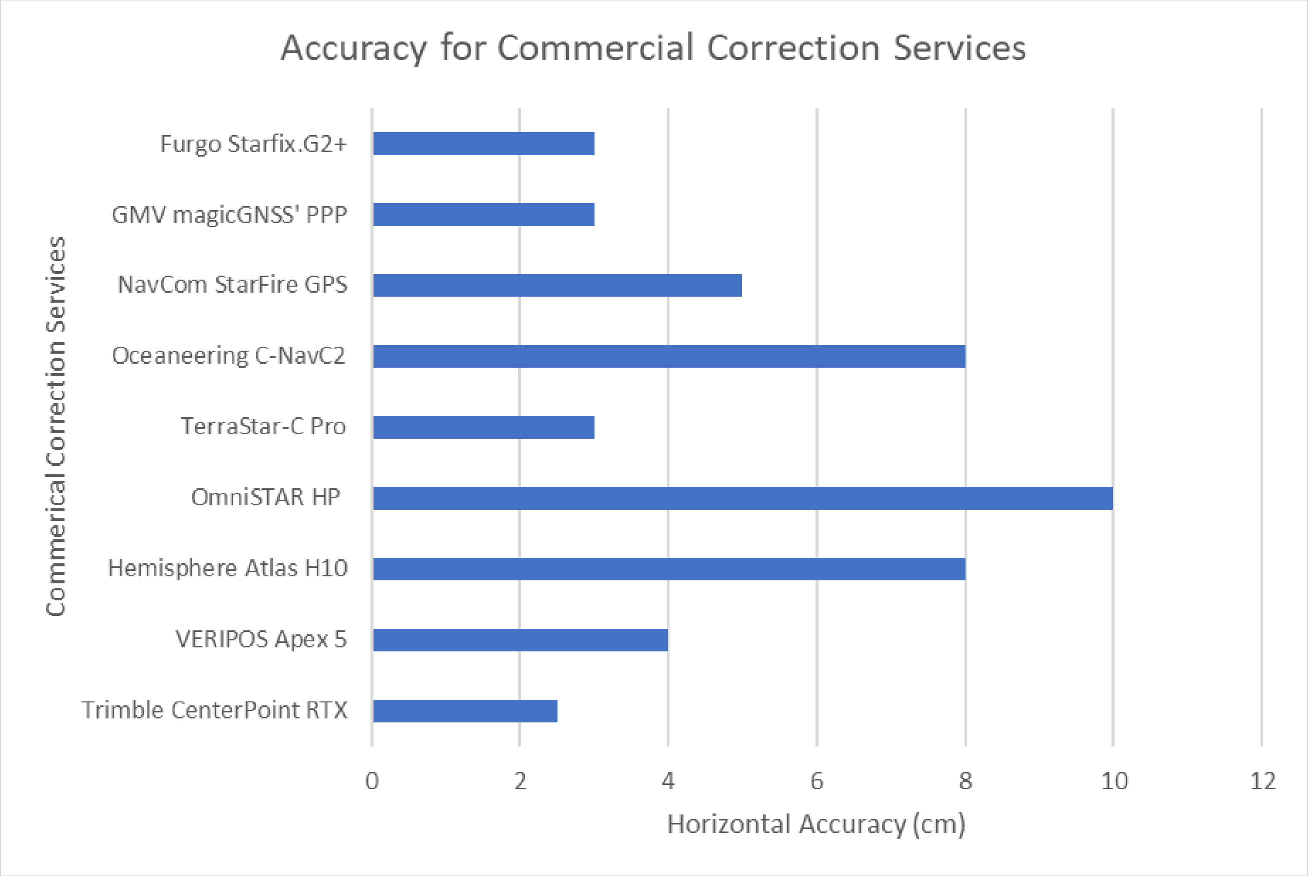
GNSS Positioning Mode: Real-time PPP Correction Service Providers

Provider	Correction Services	Observation Used	Horizontal Accuracy	Convergence Time
OmniSTAR (https://www.omnistar.com/)	OmniSTAR HP	GPS	5 – 10 cm	< 40 min
	OmniSTAR G2	GPS, GLONASS	8 – 10 cm	< 20 min
	OmniSTAR XP	GPS	8 -10 cm	< 45 min
NovAtel (https://novatel.com/)	TerraStar-C Pro	GPS, GLONASS, Galileo, BeiDou	2.5 cm (RMS) 3 cm (95%)	< 18 min
	TerraStar-C	GPS, GLONASS	4 cm (RMS) 5 cm (95%)	30 min
	TerraStar-L	GPS, GLONASS	40 cm (RMS) 50 cm (95%)	< 5 min

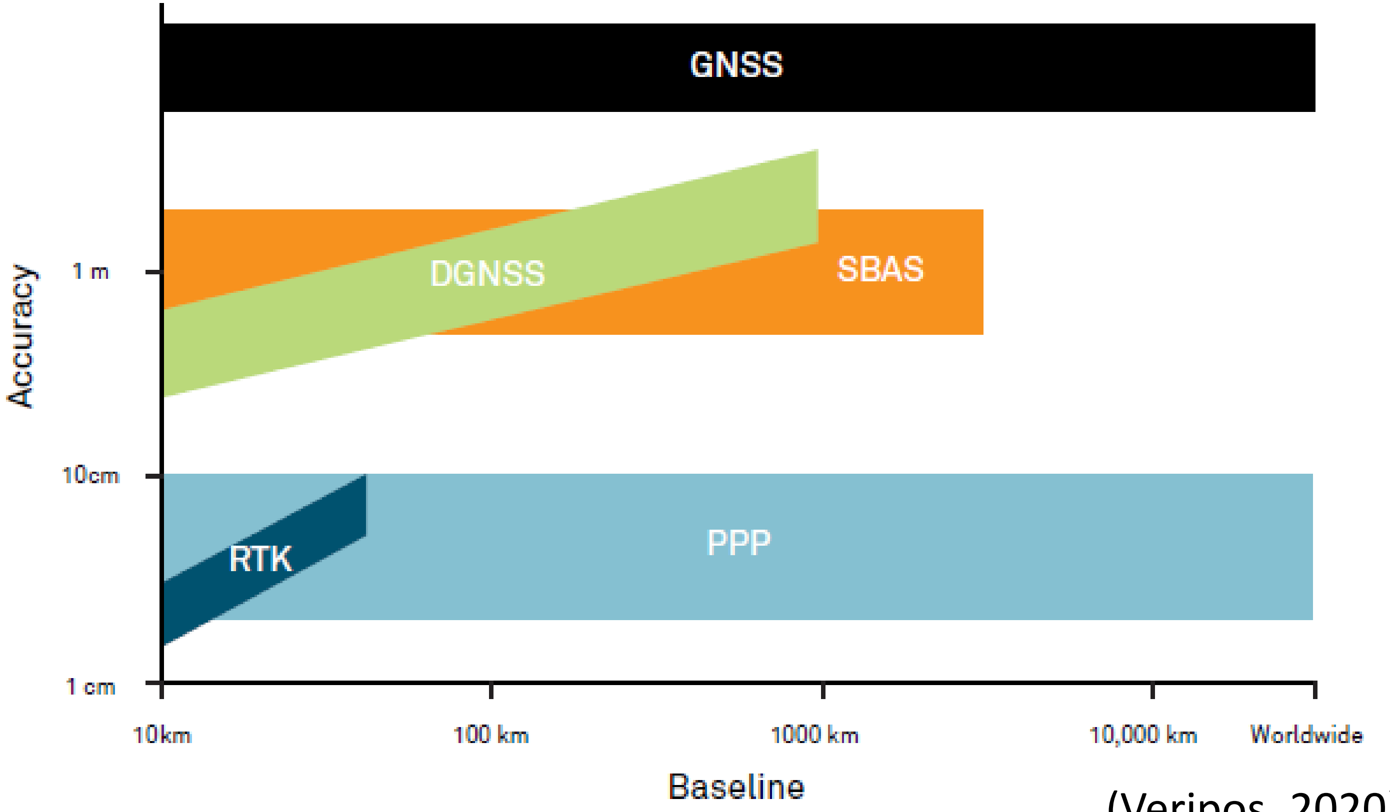
GNSS Positioning Mode: Real-time PPP Correction Service Providers

Provider	Correction Services	Observation Used	Horizontal Accuracy	Convergence Time
Oceaneering (https://www.oceaneering.com/)	C-NavC1	GPS	10 cm	
	C-NavC2	GPS, GLONASS	8 cm	
NavCom (https://www.navcomtech.com)	StarFire GPS	GPS, GLONASS	5 cm	30 – 45 min
GMV (https://magicgnss.gmv.com/)	magicGNSS' PPP	GPS, GLONASS, Galileo, BeiDou, QZSS	3 cm (95%)	20 min

GNSS Positioning Mode: Real-time PPP Correction Service Providers



GNSS Positioning Mode: Expected Accuracy of GNSS Correction Methods



(Veripos, 2020)

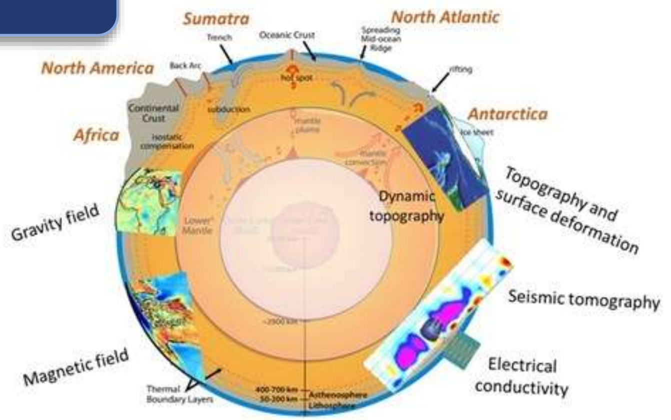
Revision of Geodetic Datum

The **Earth is dynamic** and due to that, any natural disaster (e.g., earthquake) followed by post-seismic activities happen will cause the **drifts in the tectonic plate**, hence **changing the shape** of the Earth as well as its **origin**.

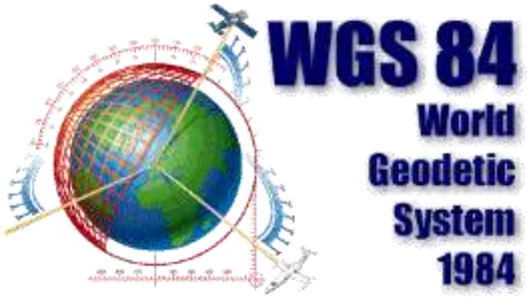
Many versions of WGS84 and ITRF were developed to ensure the **geocentric of the datum (ECEF)**.

Not all countries implement the **latest version** of datum for positioning and mapping purposes.

A **heterogeneous reference system** will complicate the surveying works and scientific research specifically when involving the **integration between land and sea**.



Global Geodetic Datum: WGS84



(https://confluence.qps.nl/qinsy/8.0/en/world-geodetic-system-1984-wgs84-182618392.html)

Short Name	Epoch	Remarks	Shift
WGS84	1984	• Realized using Doppler (1987). • Connected to ITRF90 by a 7-parameter Helmert transformation	N/A
WGS84 (G730)	1994.0	• Realized based on GPS (1994). • Coincide with ITRF91.	0.70 m
WGS84 (G873)	1997.0	• Realized based on GPS (1997). • Coincide with ITRF94.	0.20 m
WGS84 (G1150)	2001.0	• Realized based on GPS (2002). • Coincide with ITRF2000.	0.06 m
WGS84 (G1674)	2005.0	• Realized based on GPS (2012). • Coincide with ITRF2008.	0.01 m
WGS84 (G1762)	2005.0	• Realized based on GPS (2013). • Coincide with ITRF2008.	0.01 m
WGS84 (G2139)	2005.0	• Realized based on GPS (2021) • Coincide with ITRF2014.	*No information*

"New realizations of WGS84 based on GPS data, such as G730, G873, G1150, G1674 and G1762. These new WGS84 realizations are coincident with ITRF at about 10-centimeter level." (QPS, 2020)

(https://itrf.ign.fr/ITRF_solutions/)

International Terrestrial Reference Frame ITRF

IERS

IAG

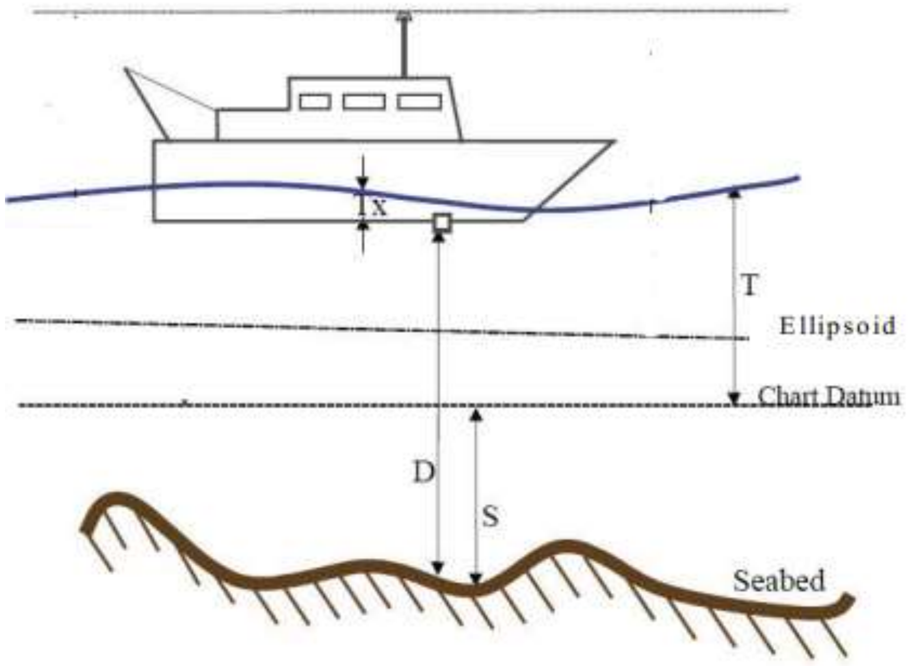
Global Geodetic Datum: ITRF

Short Name	Epoch	Remarks
WGS84	1984	• Since 1997, WGS84 has been maintained within 10 cm of the current ITRF.
ITRF88 – ITRF97	1984.0	• Origin at geocentre, orientated to the BIH Terrestrial System. • Datum defined by a set of 3D Cartesian station coordinates.
ITRF2000	1997.0	• Origin at geocentre, orientated to the BIH Terrestrial System. • Datum defined by a set of 3D Cartesian station coordinates.
ITRF2005	2000.0	• Origin at geocentre, orientated to the BIH Terrestrial System and adjusted to a zero net rotation. • Defined by time series of Cartesian station coordinates and Earth rotation parameters.
ITRF2008	2005.0	• Origin at geocentre. • Defined by null translation parameters and rates between ITRF2008 and ILRS SLR time series.
ITRF2014	2010.0	• Origin at geocentre. • Defined by zero translation parameters and rates between ITRF2014 and ILRS SLR time series.

Practices in Hydrography

Traditional / Current Practice

- **Hydrographic surveys** have traditionally been conducted with reference to the **tidal based chart datum**.
- Topography acquires **relative to the geoid** (i.e. the geodetic datum realized by the mean sea level).
- **DGNSS or Real-time PPP techniques** have been mostly adopted for the hydrographic surveys due to the fact that it offers **modest positioning accuracy** (or uncertainty), especially for the horizontal component.



Note:

- *Only horizontal coordinates are taken for bathymetric modelling*
- *Vertical reference is given by relation between Instantaneous water surface and chart datum*

$$S = D + Tx - T$$

S = Charted Depth
D = Sounding Depth
Tx= Draft vessel correction
T = Tidal correction

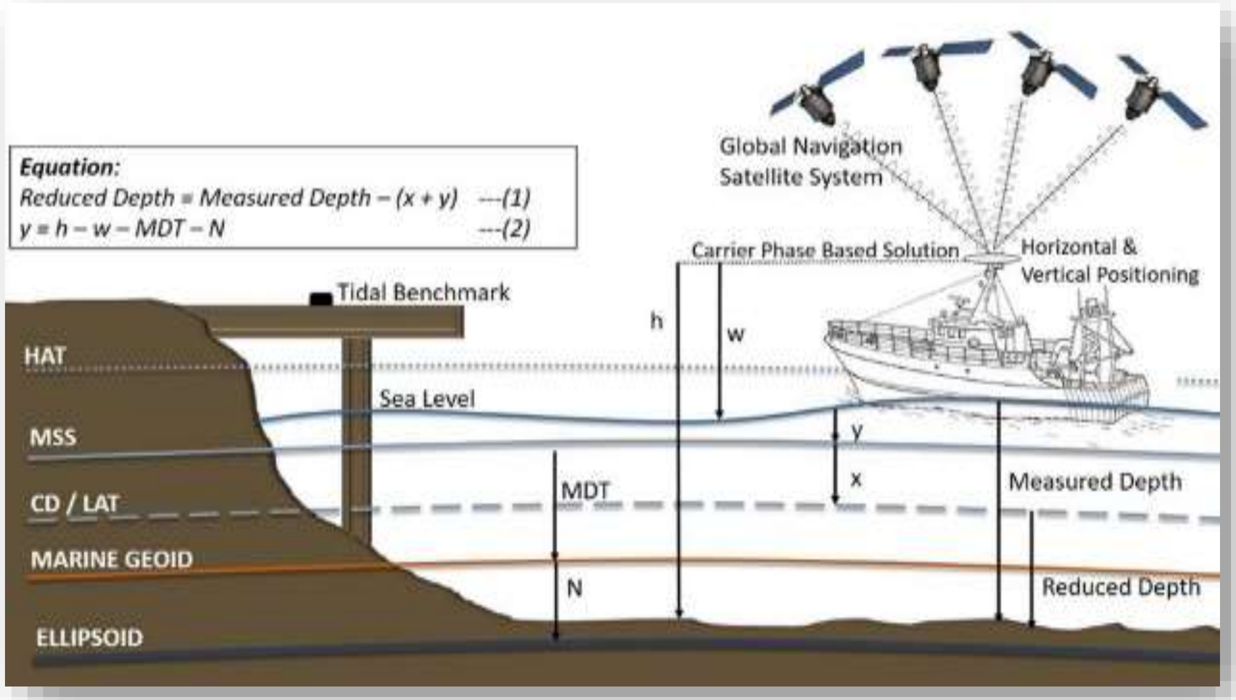
(Adapted from Greenland & Higgins, 2006)

Practices in Hydrography

Future Practice

- Development of a **vertical separation model (VSEP)** will allow easier **assimilation of land and maritime data** resulting in **seamless vertical data**.
- Using **GNSS (RTK, PPK, PPP)**, sounding depth can be obtained by **subtracting** the **height of the vessel's antenna** above the **ellipsoid** and the **ellipsoid/CD separation value**, **N**, from the **height of the antenna** above the seabed.
- **Charted depth** becomes a **derived product**.

Ellipsoidally Referenced Surveying Technique

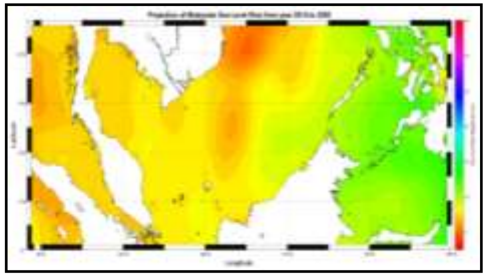


Note:

- *Modern hydrographic surveying, in conjunction with high accuracy GNSS, negate the need to measure tides, dynamic vessel draft and, depending on the accuracy of the GNSS system – FIG Publication 37 (Greenland & Higgins, 2006)*

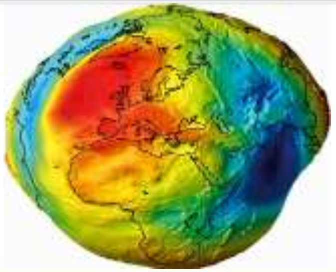
Applications on Land and Sea

Sea Level Rise

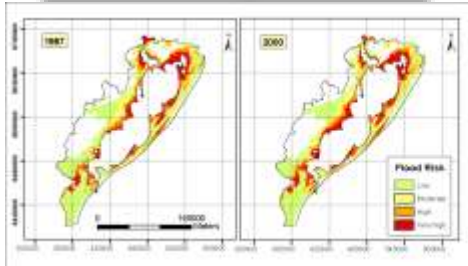


Coastal Inundation

Coastal Geoid

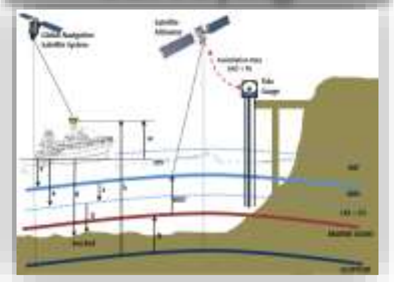


Coastal Mapping & Management



(Silva et al., 2012)

Ellipsoidally Referenced Surveying



Concluding Remarks

- The need to understand the evolution of **hydrographic positioning** is important as the **techniques are enhanced based on the current technologies**.
- A **homogenous coordinate system** by reference to the same datum is required for positioning and mapping **integrated purposes (i.e., land and water management at inshore)**.
- The implementation of **reference datum in hydrographic survey practices** relative to **GNSS** technologies, should **mention the adopted version** of datum, i.e., WGS84 (G2139) and ITRF (2014).
- Depending on the **required accuracy** of the measurement purposes, the GNSS positioning technique chosen must be well-suited with respect to the **latest geodetic datum.**
- A further study on the **differences between series of WGS84 and ITRF using absolute and relative positioning** is required to evaluate the positional accuracy in **hydrographic practices**.