Geomatics Engineering Department

Second Year Geomatics

Geodesy 2 (GED209)

Lecture No: 9

Height Systems

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Overview Of Previous Lecture

History of Egyptian Geodetic Networks

Description Of Network (1)

Description Of Network (2)

Satellite Networks In Egypt

Summary

Overview Of Today's Lecture

- What is Height?
- What is a Height System?
- Vertical Datum
- Common Height Systems
- Height Determination Using Gravity Observations
- International Height Reference System (IHRS)
- Online Resources

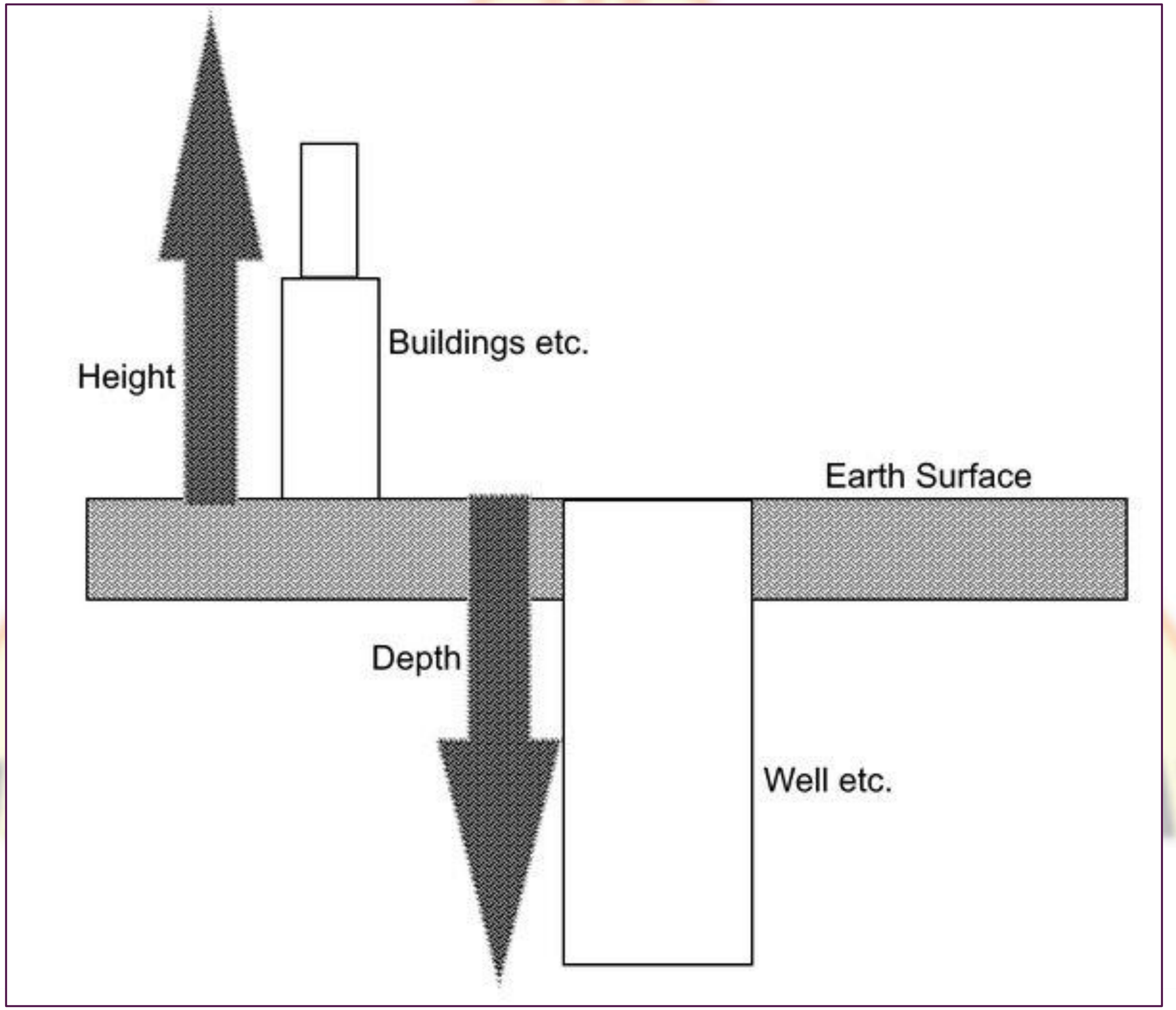
EXPECTED LEARNING OUTCOMES

- learn the definition and purpose of a height system, which is a framework used to measure and describe elevations or heights of points on the Earth's surface.
- Gain knowledge about vertical datums, which are reference surfaces or planes used to measure elevations relative to a specific point.
- Learn about various common height systems used worldwide.
- Learn about the role of gravity observations in determining heights.
- Gain knowledge about the IHRS, which is a global reference system for heights.

What is Height?

HEIGHT

- Height above or below a reference surface.



What is A Height System?

Height System

- A height system is a one-dimensional coordinate system used to express the metric distance (height) of a point above a reference surface (i.e., the zero-height level).

Vertical Datum

- **Commonly adopted criteria for a vertical datum include the following approaches:**

1. Tides, based on sea level when specific conditions occur.
2. Gravimetric, based on a geoid; or geometric, based on the same Earth ellipsoids that are used in computing a horizontal datum.

Types of Heights

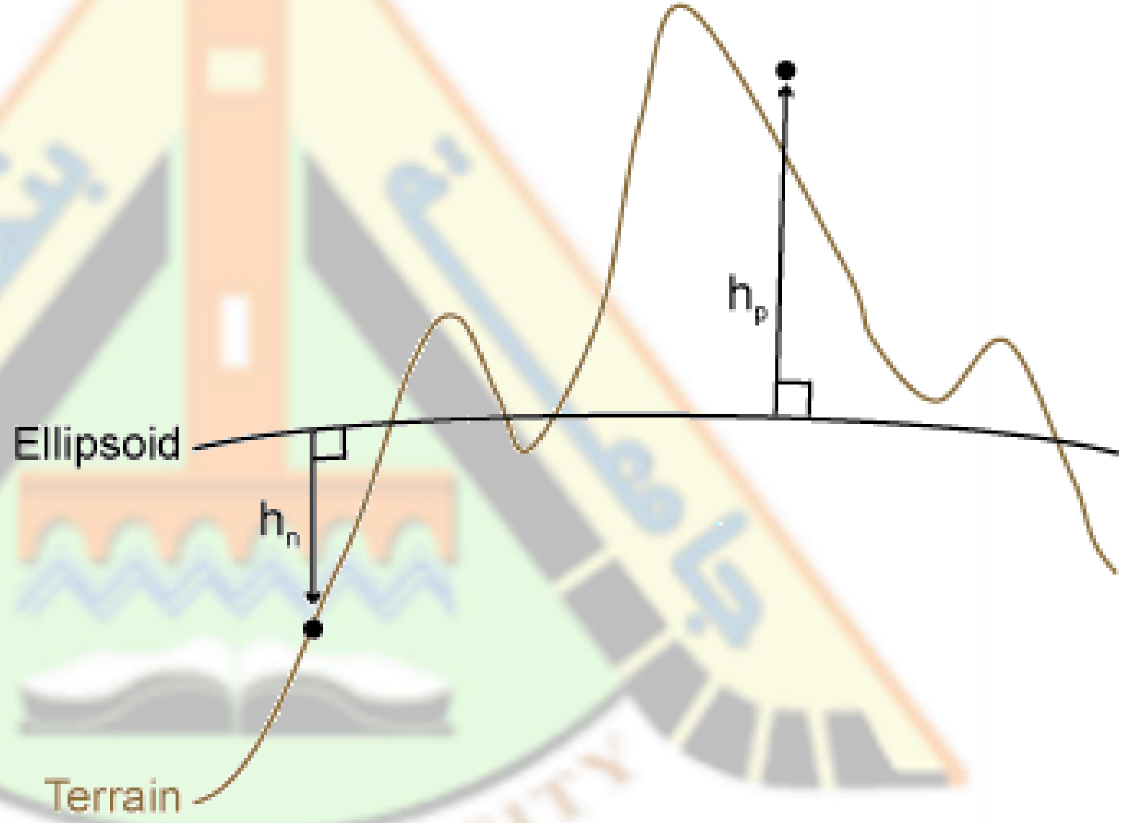
Types of Heights

1. Ellipsoidal Height
2. Orthometric Height
3. Normal Height
4. Dynamic Height

TYPES OF HEIGHTS

1. **Ellipsoidal Height (*h*) :** is height measured along a normal of a reference ellipsoid.

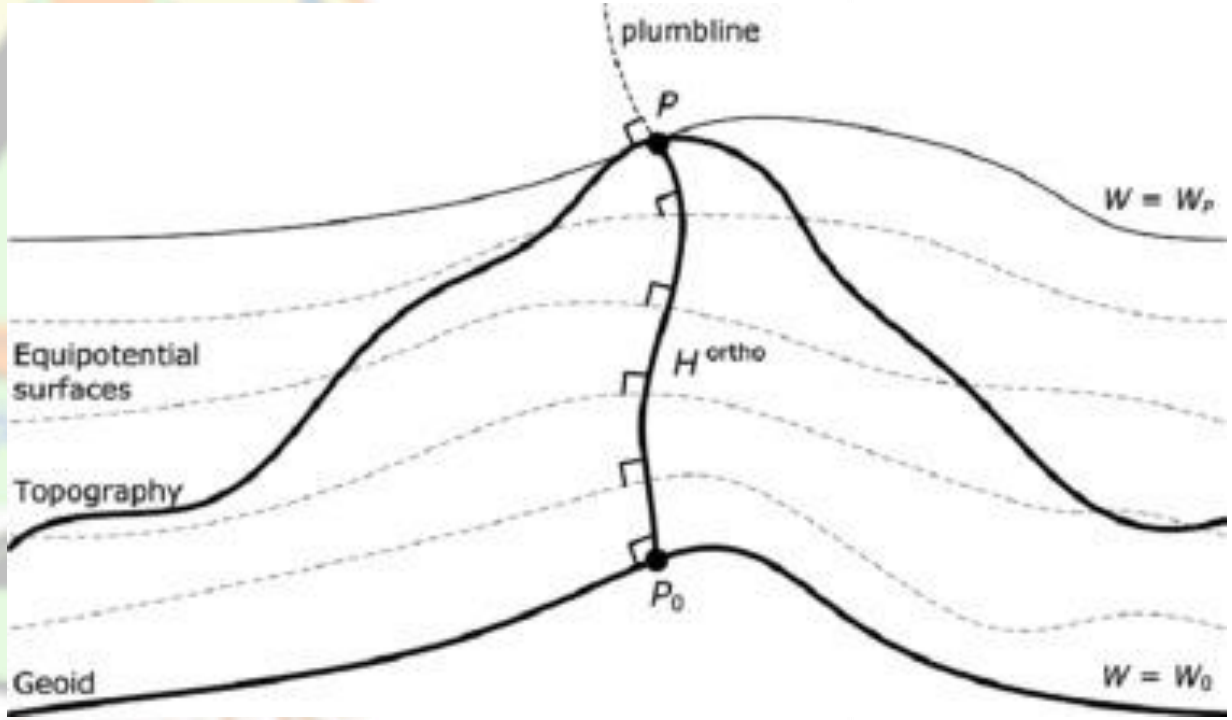
- Positive +*ve* up the ellipsoid
- Negative -*ve* down the ellipsoid



Types of Heights

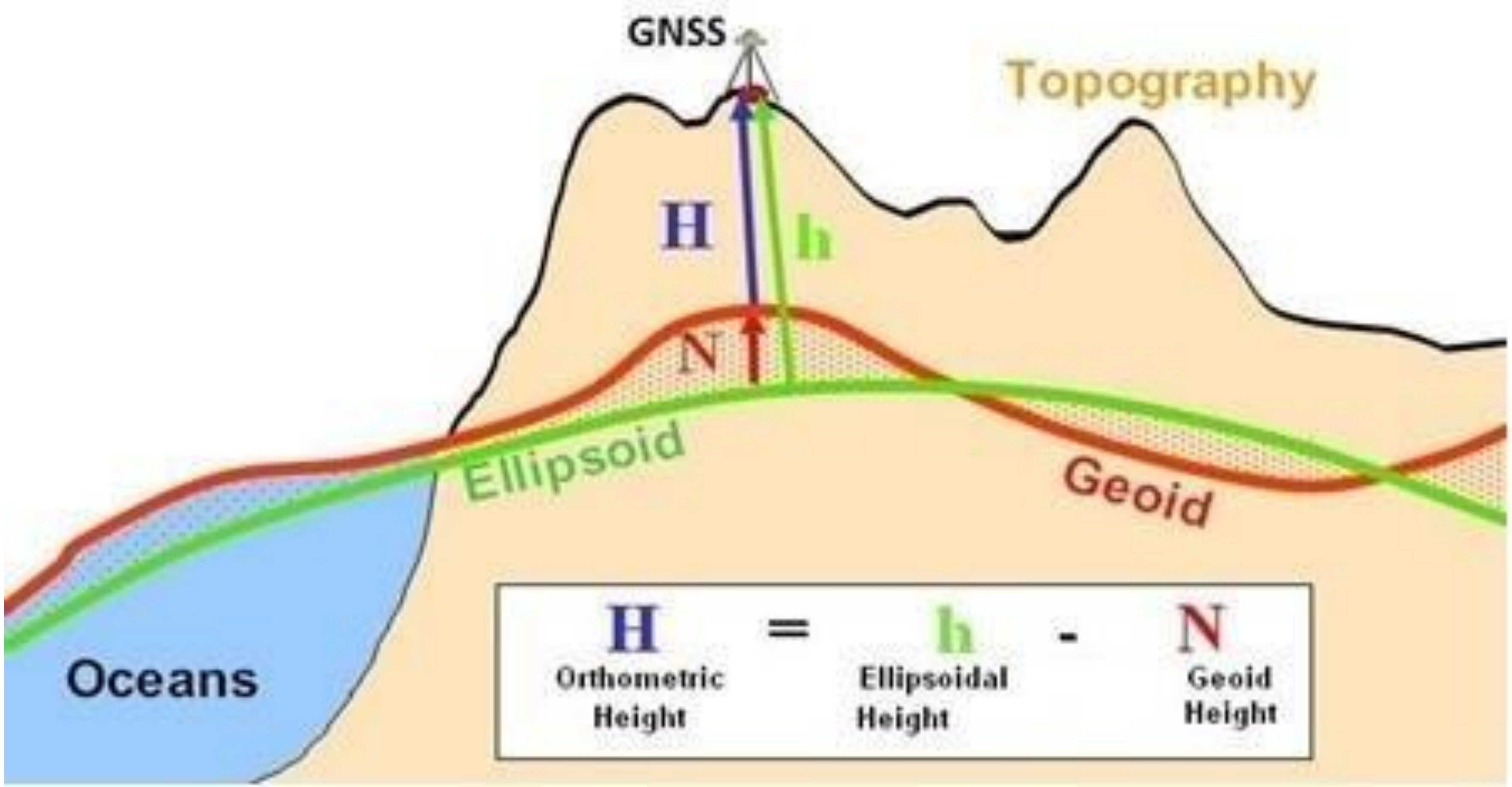
2. **Orthometric Height (*H*) :** is the vertical distance along the plumb line from a point of interest to a reference surface known as the geoid. It is mostly used in surveying tasks and topographic mapping.

- Positive +*ve* up the geoid
- Negative -*ve* down the geoid



Types of Heights

Orthometric Height (*H*) Vs Ellipsoidal Height



How to determine orthometric heights?

Determination of Orthometric Height

1. Spirit leveling.
2. Gravity observations along the leveling path.
3. GPS combined with ***geoid models*** $H = h - N$ (low accuracy solutions).

- The geoid models the average sea level of the Earth without effects such as weather, tides, and land.
- A geoid model is created by measuring variations in the Earth's gravitational field, so it has a smoothly undulating shape.

Are gravity observations essential with spirit leveling?

Determination of Orthometric Height

- **Are gravity observations essential with spirit leveling?**

- Yes, because the sum of the measured height differences along the leveling path between points A and B is not equal to the difference in orthometric height between points A and B.

How?

Determination of Ellipsoidal Height

- As mentioned, *H* is measured along the *curved* plumb line perpendicular to equipotential surfaces.
- Equipotential surfaces are rather complicated mathematically and they are not parallel to each other.
- **Accordingly**,

1. Orthometric heights are not constant on the equipotential surface.
2. Points on the same level surface would have different orthometric heights.

Before We Continue!

Geopotential Numbers

- The difference in height, dh, measured during each set up of leveling can be converted to a difference in potential by multiplying dh by the mean value of gravity, g_m, for the set up (along dh).

$$Geopotential\ difference = gm \times dh$$

- Geopotential number C, or potential difference between the geoid level W_0 and the geopotential surface W_P through point P on the Earth surface, is defined as: -

$$\int_0^P g\,dh = C = W_0 - W_P$$

Where g is the gravity value along the leveling path.

- This formula is used to compute C when g is measured and is independent on the path of integration.

Geopotential Numbers

- Since the computation of C is not path-dependent, the geopotential number can be also expressed as: -

$$C = g_m \times H,$$

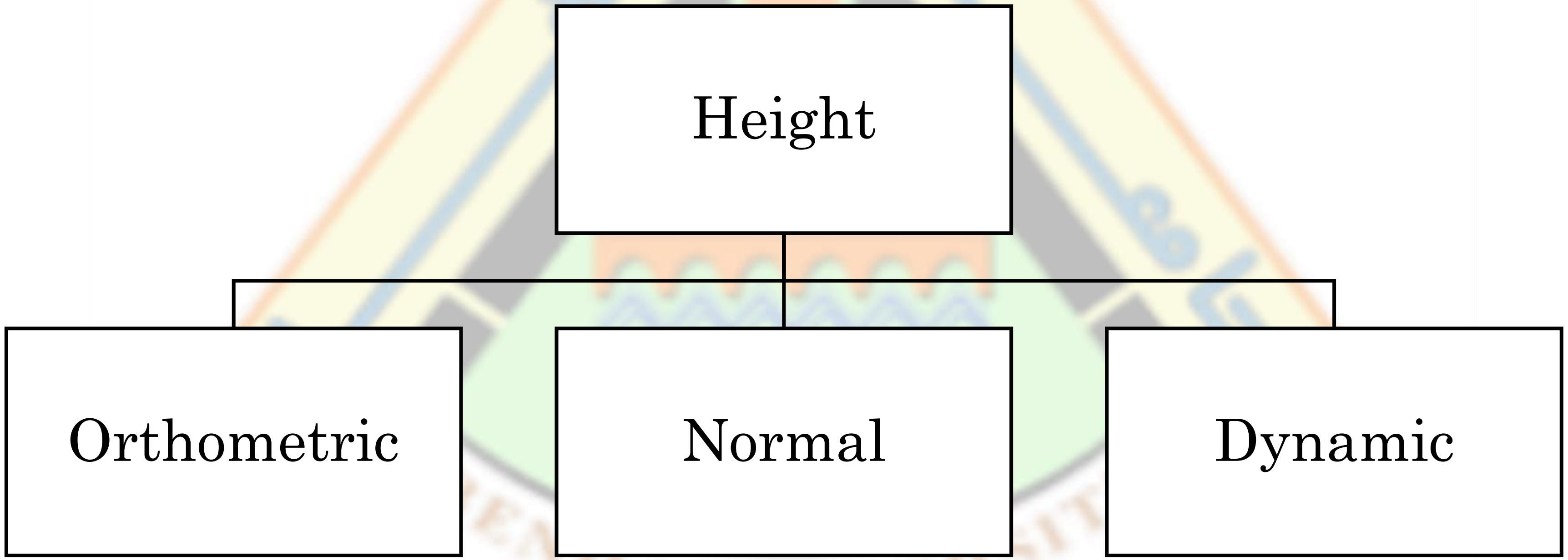
where H is the height above the geoid (mean sea level) and g_m represents the mean value of gravity along H.

- Geopotential number is constant for the geopotential (level) surface.
- Geopotential numbers can be used to define height and are considered a natural measure for height.

Geopotential Numbers

- Geopotential numbers can then be converted to heights: -

$$Height = \frac{C}{gravity}$$



Geopotential Numbers

- To convert the results of leveling to orthometric heights we need gravity inside the earth (along the plumb line): -
- Because we cannot measure it directly, as the reference surface lies within the Earth, beneath the point, we use special formulas to compute the mean value of gravity, along the plumb line, based on the surface gravity measured at point *P*.
- Reduction formulas used to compute the mean gravity, g_m, based on gravity measured at point *P* on the Earth surface led to:-

$$Orthometric\ Height = \frac{C}{g_m}$$

GEOPOTENTIAL NUMBERS

- The reduction formula used to compute mean gravity, based on normal gravity at point *P* on the Earth surface leads to: -

$$Normal\ Height, H^{*} = \frac{C}{\gamma_m}$$

Where γ is so-called normal gravity (model) corresponding to the gravity field of an ellipsoid of reference (Earth best fitting ellipsoid).

- If γ_{45} is considered at latitude 45 degrees, this case defines dynamic height.

$$Dynamic\ Height, H_D = \frac{C}{\gamma_{45}}$$

Geopotential Numbers

- Sometimes, instead of formulas provided above (involving *C*), it is convenient to use correction terms and apply them to the sum of leveled height differences:
- Consequently, the measured elevation difference has to be corrected using so called orthometric correction to obtain orthometric height (height above the geoid).
- Max orthometric correction is about 15 cm per 1 km of measured height difference.
- Or, the measured elevation difference has to be corrected using so-called dynamic correction to obtain dynamic height (no geometric meaning and factual reference surface; defined mathematically).
- Or, normal correction is used to derive normal heights.
- All corrections need gravity information along the leveling path (equivalent to computation of C based on gravity observations)

NOTES ON HEIGHT SYSTEMS

- Dynamic heights are constant for the level surface and have no geometric meaning.
- Orthometric heights differ for points on the same level surface because the level surfaces are not parallel. They are measured along the curved plumb line with respect to geoid level.
- Normal height of point P on earth surface is a geometric height above the reference ellipsoid of the point Q on the plumb line of P such as normal gravity potential and Q is the same as actual gravity potential at P.
- Normal heights are measured along the normal plumb line ("normal" refers to the line of force direction in the gravity field of the reference ellipsoid (model)).
- All above types of heights are derived from geopotential numbers.

Notes on Height Systems

- A disadvantage of orthometric and normal heights is that neither indicates the direction of flow of water. Only dynamic heights possess this property.
- That is, two points with identical dynamic heights are on the same equipotential surface of the actual gravity field, and water will not flow from one to the other point.
- Two points with identical orthometric heights lie on different equipotential surfaces and water will flow from one point to the other, even though they have the same orthometric height.
- The last statement holds for normal heights, although due to the smoothness of the normal gravity field, the effect is not as severe

Unified Vertical Datum

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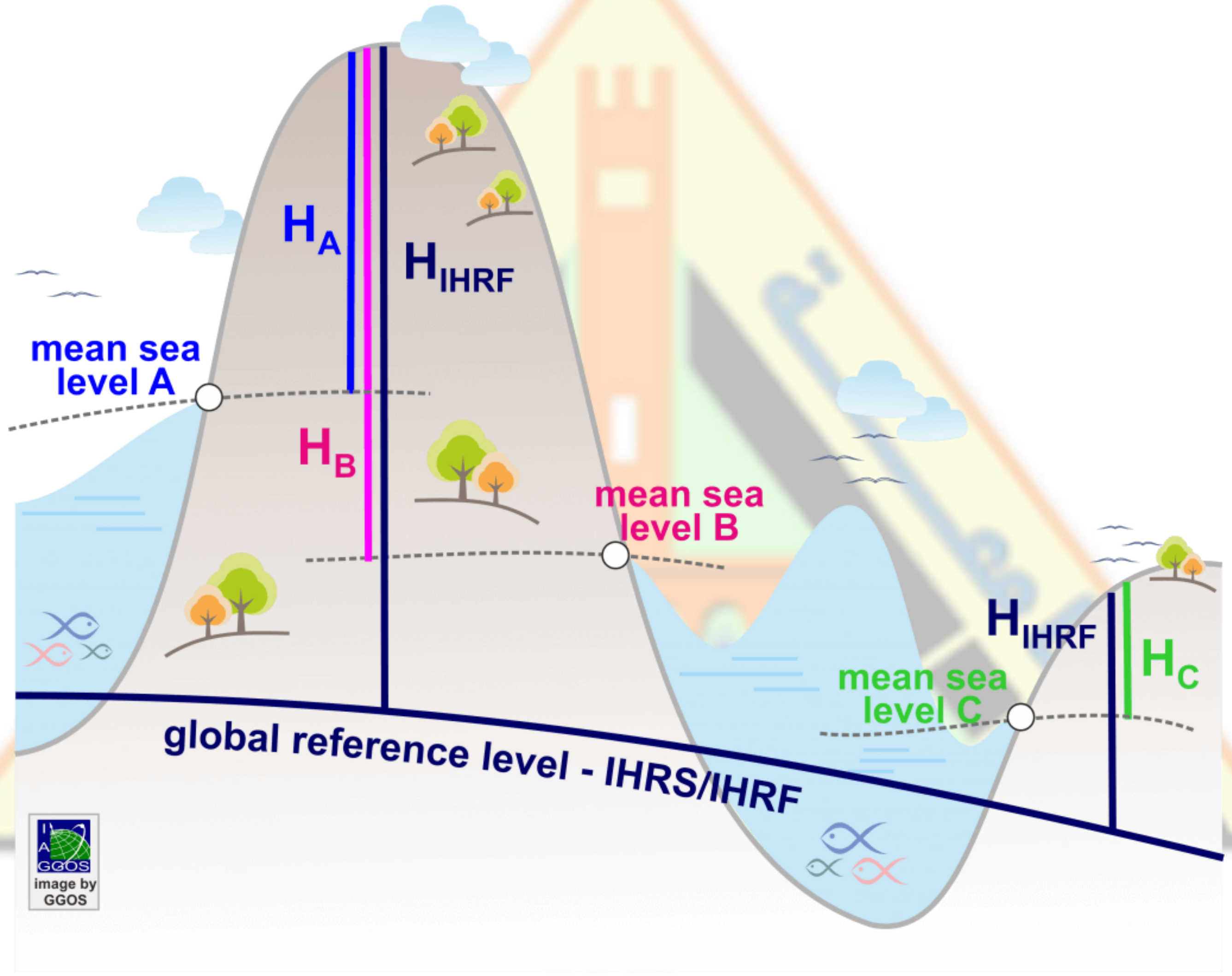

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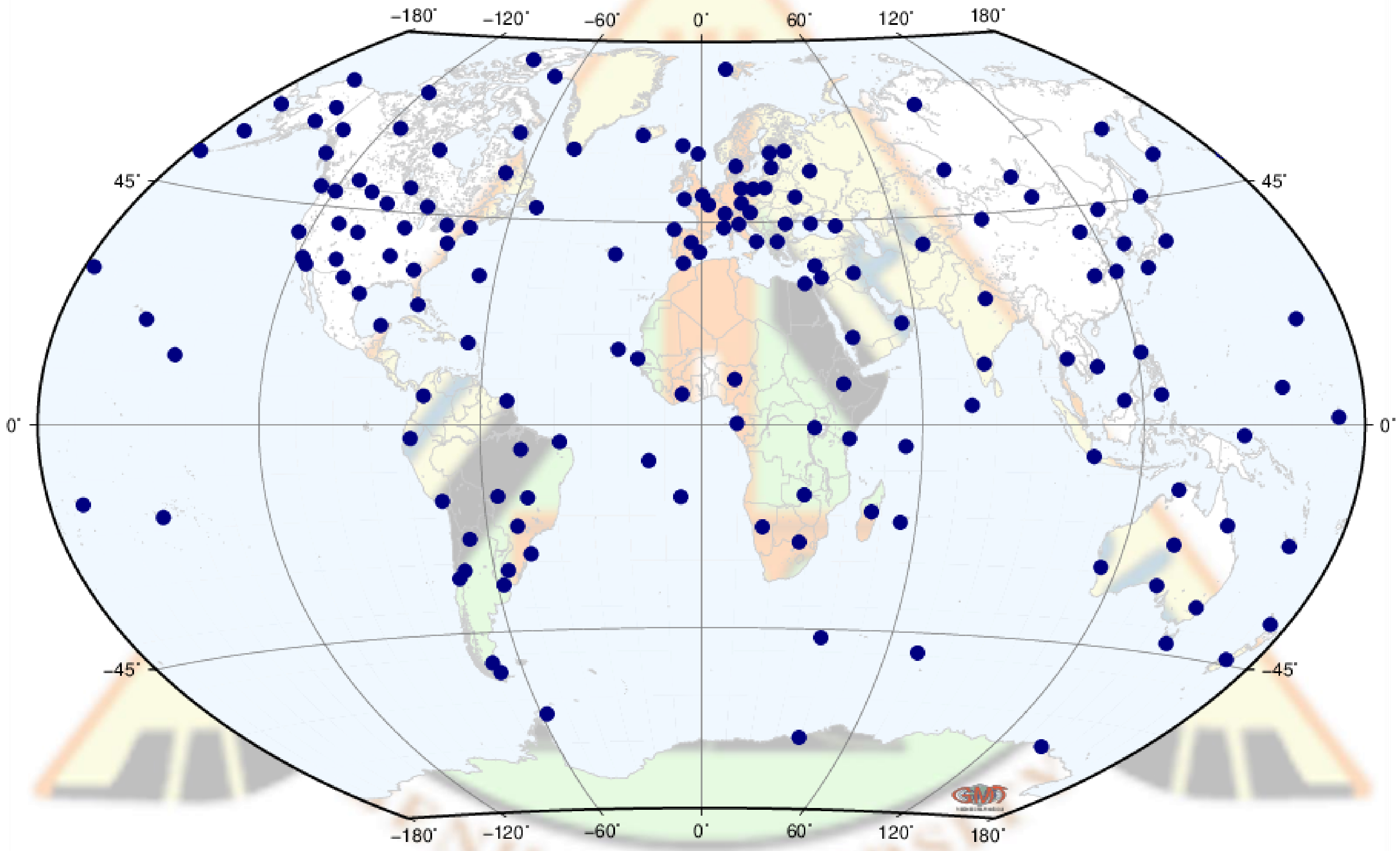
International Height Reference System (IHRS)

- A global unified height system: the zero-height level is a global equipotential surface of the Earth's gravity field and the vertical coordinate of any point on the Earth's surface is the level difference with respect to that global equipotential surface.
- Heights referring to the IHRS are consistent globally and do not depend on the local sea levels.
- The realization of the IHRS is the International Height Reference Frame (IHRF): a set of reference stations homogeneously distributed over the world and with known geopotential numbers or height values referring to the IHRS.

INTERNATIONAL HEIGHT REFERENCE SYSTEM (IHRS)



IHRF reference network

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https://ggos.org/item/height-reference-frame/

Online Resources

- Global Geodetic Observing System - GGOS (https://ggos.org/item/height-reference-frame/)

End Of Presentation

Thank You For Attention!