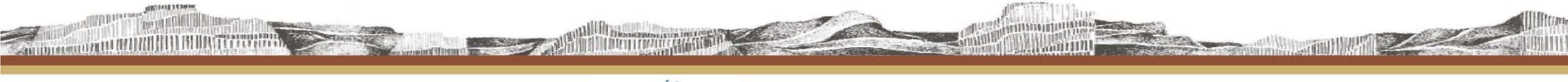
Reference Systems & Global and Local Reference Frames

Aslam Parker / Dr S Mphuti

Chief Director:: National Geospatial Information,

Branch National Geomatics Management Service



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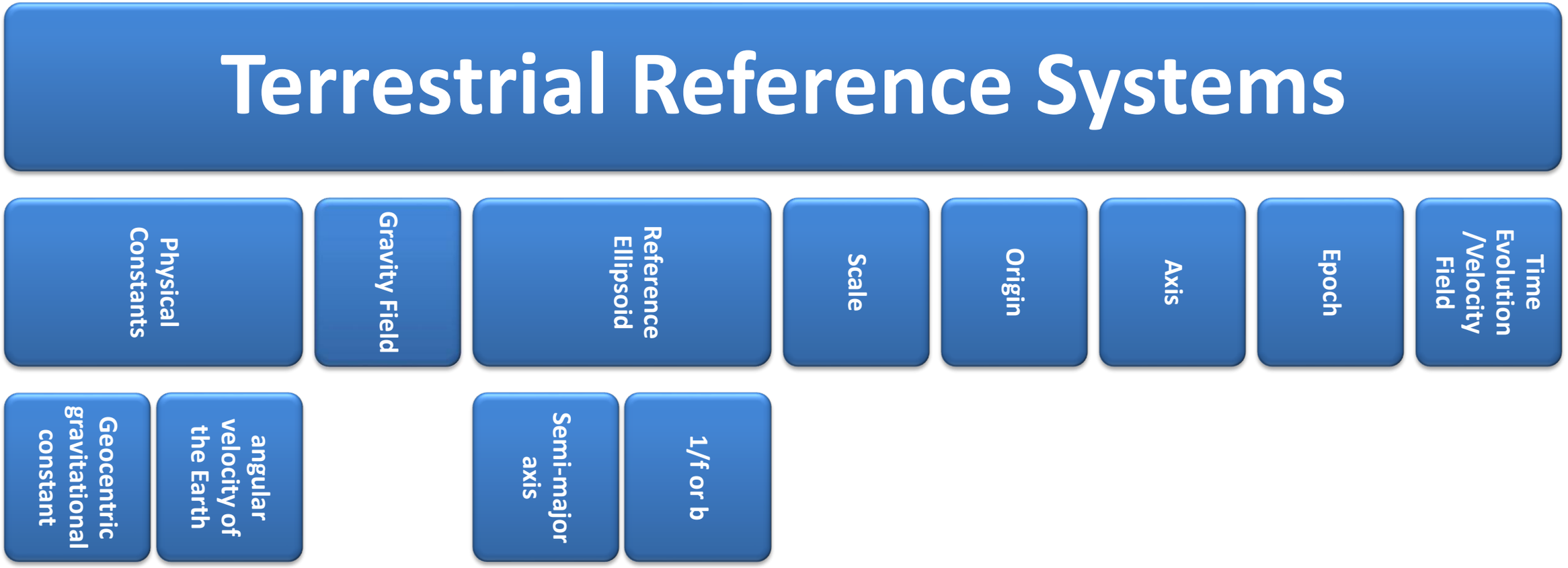
Terrestrial Reference Systems

- Terrestrial Reference Systems describes procedures for creating reference frames suitable for use with measurements on or near the Earth's surface.
- This is done in much the same way that a physical standard might be described as a set of procedures for creating a realization of that standard.


334ft (101 metres)
The modern reference meridian indicating zero longitude using GPS
Greenwich Park
Peter Harrison Planetarium
Royal Observatory Greenwich
The Airy meridian marked as the Prime Meridian of the World


ECUADOR
0° - 0' - 0" LAT.

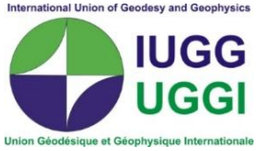
Terrestrial Reference Systems



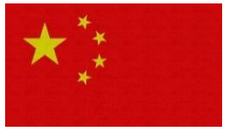
Global Terrestrial Reference Systems

- World Geodetic System 84 (WGS 84)
- Geodetic Reference System 80 (GRS80)

and its successor



- International Terrestrial Reference System (ITRS).



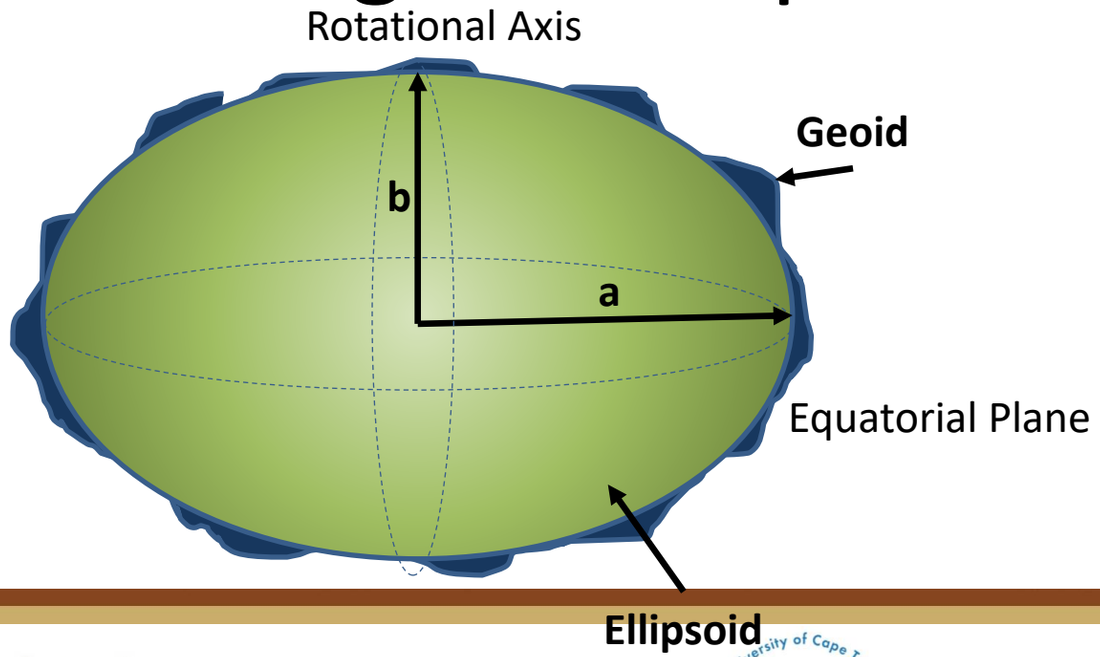
- China Geodetic Coordinate System 2000
- ПЗ-90 (PZ-90, “Parametry Zemli 1990”)

Terrestrial Reference Frames

- Reference Frame - Realization of the Reference System through observation - (e.g. GNSS, VLBI,SLR, DORIS, Leveling)
- ITRF Currently the work of the International Earth Rotation and Reference System Service (IERS)
- In practice the Reference Frame can be considered the same as a datum

Spheroid (oblate ellipsoid of revolution)

- Most common mathematical approximation describing the shape of the earth.



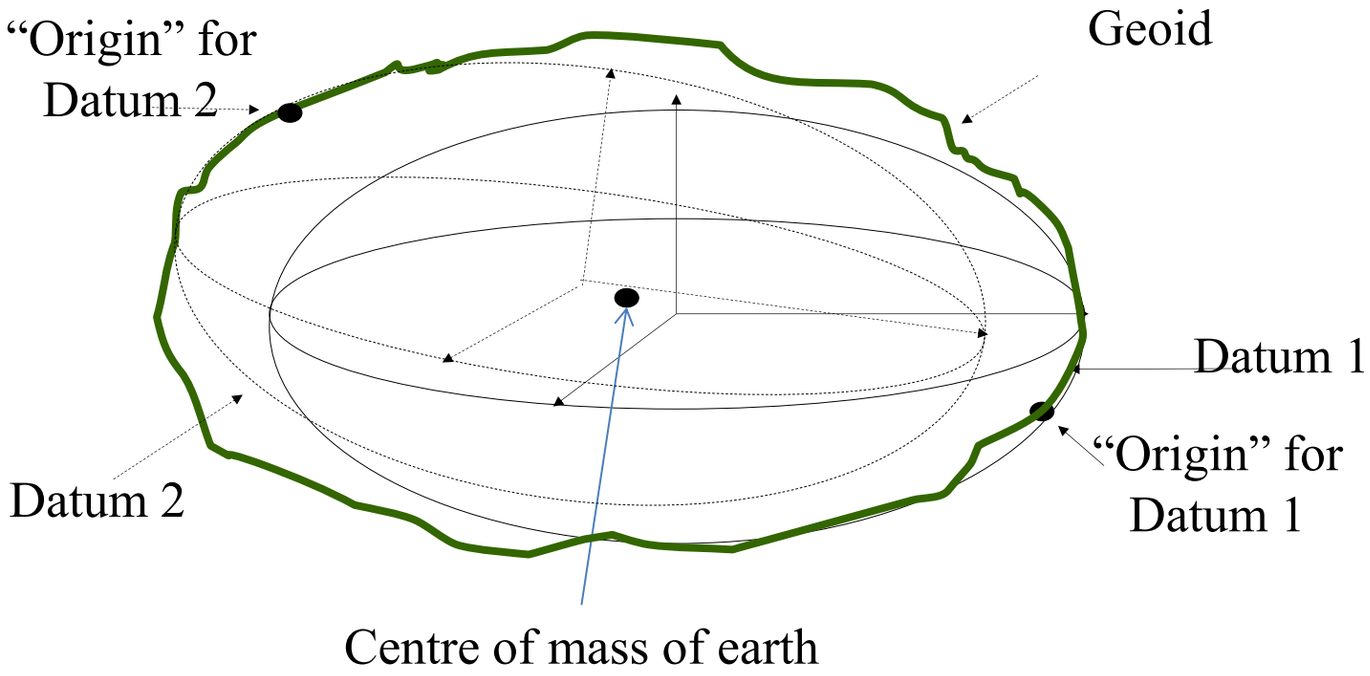
Elements of the Ellipsoid:

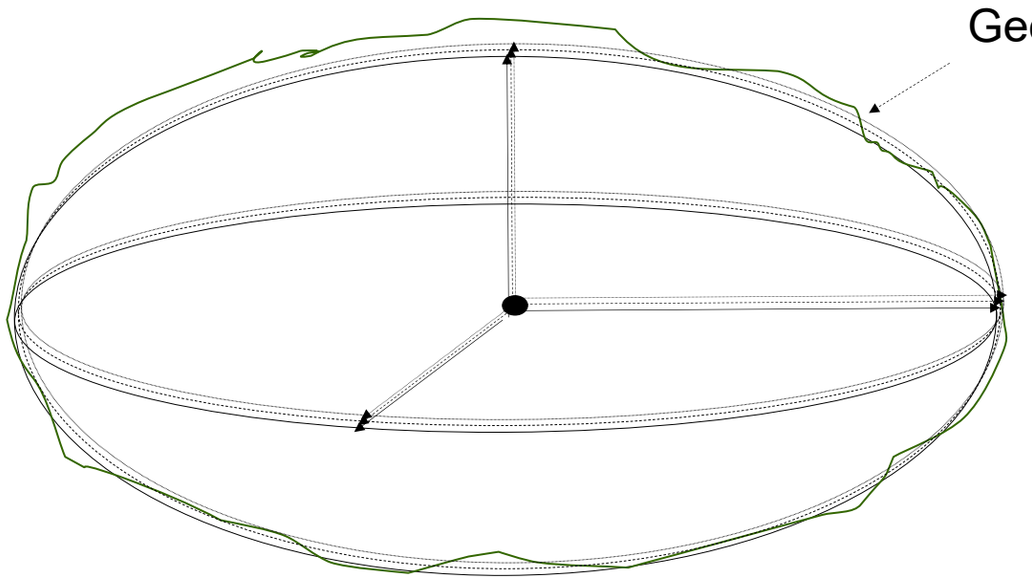
a = semi major axis

b = semi minor axis = a(1-f)

1/f (inverse flattening) = a/(a-b)

Geocentric vs Non-Geocentric Reference Frames



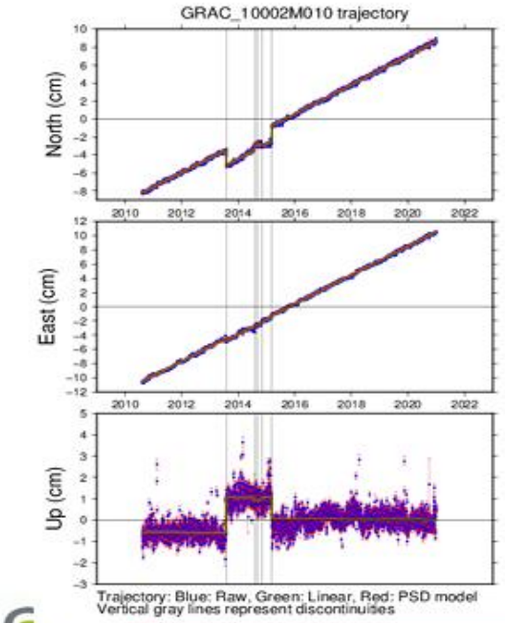


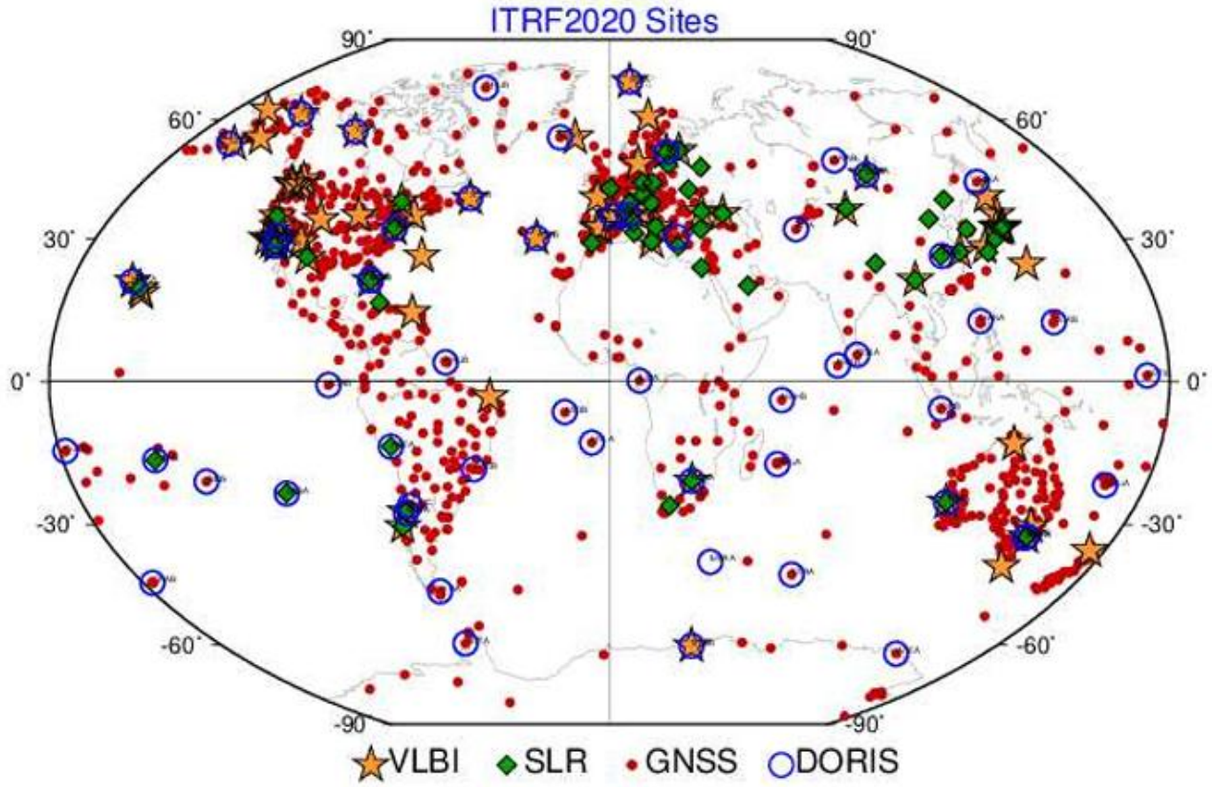
International Terrestrial Reference Frames

- International Terrestrial Reference Frames (ITRF's) are realizations of the ITRS and Produced by the IERS.
- Coordinates obtained by combination of individual TRF solutions computed by IERS analysis centres using the rigorous combination of observations of Space Geodesy techniques: GNSS , VLBI, SLR, LLR and DORIS.

ITRF2020 Network

- 1223 sites
  - 878 Northern hemisphere
  - 355 Southern hemisphere
- 1800 stations
- 3106 discontinuities
- ~1159 GNSS sites
  - 1344 stations
  - 2938 discontinuities





DORIS

GNSS

SLR

VLBI

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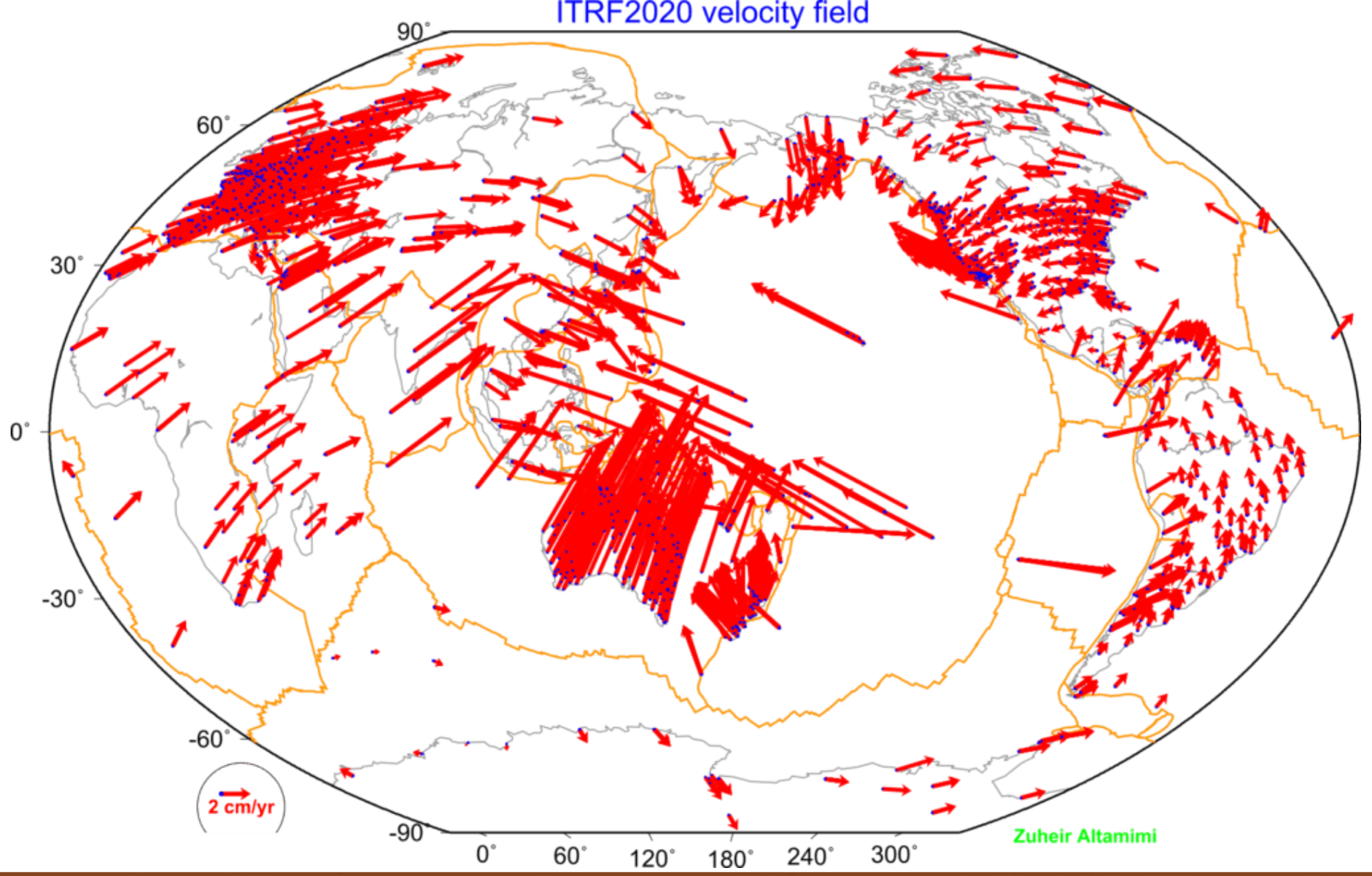

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ITRF (realizations of ITRS)

- ITRF solutions consist of sets of station positions and velocities with their variance/covariance matrices.
- Since the release of the ITRF2005 , Earth Orientation Parameters (EOP's) have simultaneously been combined with station coordinates.
- The numbers (yy) following the designation "ITRF" specify the last year when data was used during frame processing.

ITRF solutions available :

https://itrf.ign.fr/en/homepage

- **ITRF2020**
- **ITRF2014 TrigNet realisation at epoch 2018.18**
- **ITRF2008**
- **ITRF2005 SAGEOID2010 referenced to this (epoch 2010.02)**
- ITRF2000
- ITRF97
- ITRF96
- ITRF94
- ITRF93
- ITRF92
- **ITRF91 Hartebeesthoek94 (SA realisation, epoch 1994.0)**
- ITRF90
- ITRF88
- ITRF89

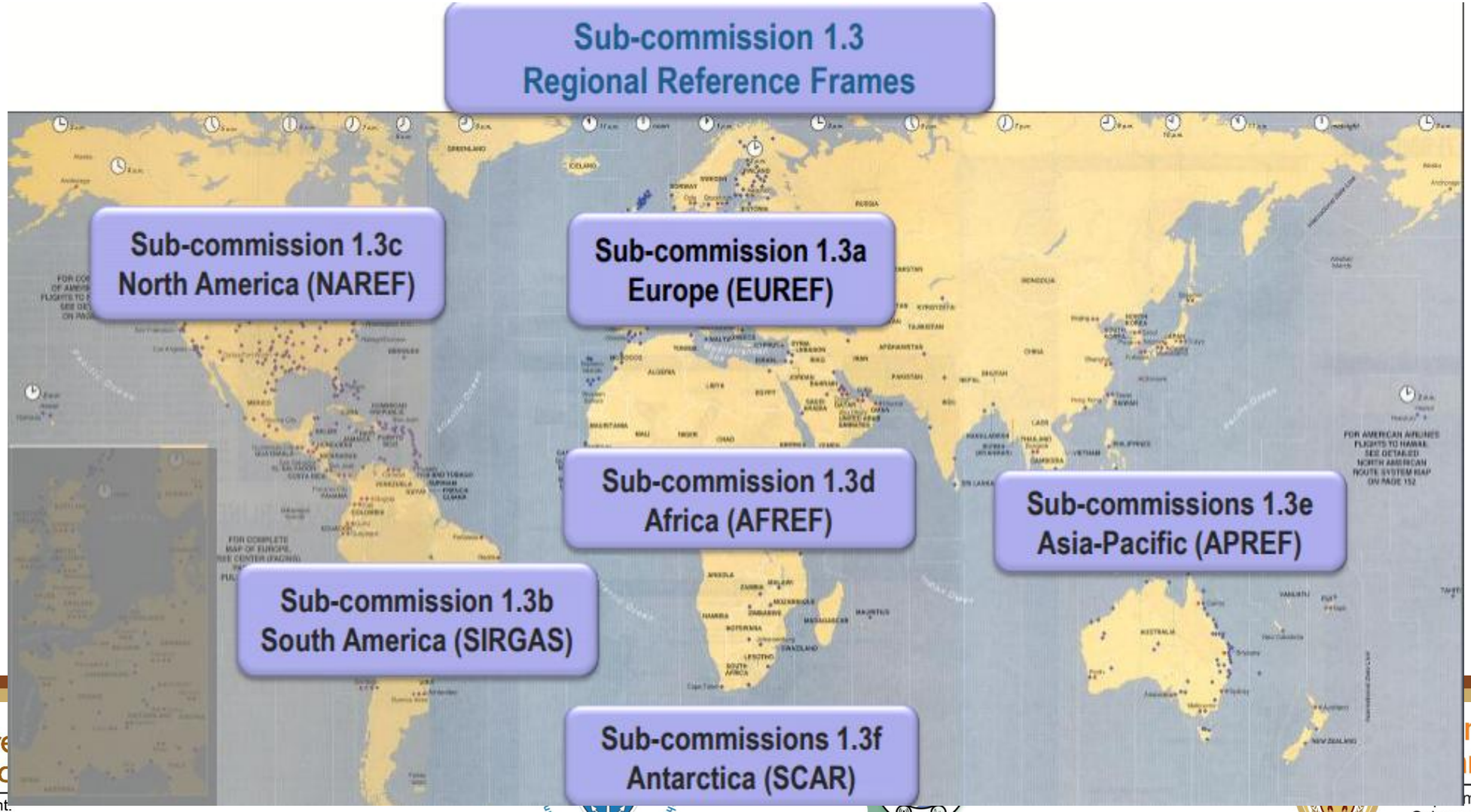
WGS84 RF's

- The current realization of the WGS 84 Reference System is designated as WGS 84 (G2269) Reference Frame.
- GPS Operational Control Segment (OCS) implemented WGS 84 (G2269) on 7 Jan 2024 with NGA implementation on the same date.
- WGS 84 (G2269) aligns WGS 84 with ITRF 2020 (epoch 1 Jan 2024) with accuracy better than one cm-per-component, resulting in an overall difference of less than one cm. … based on a subset of IGS stations selected as control points in the reference frame solution.

Regional Reference Frames

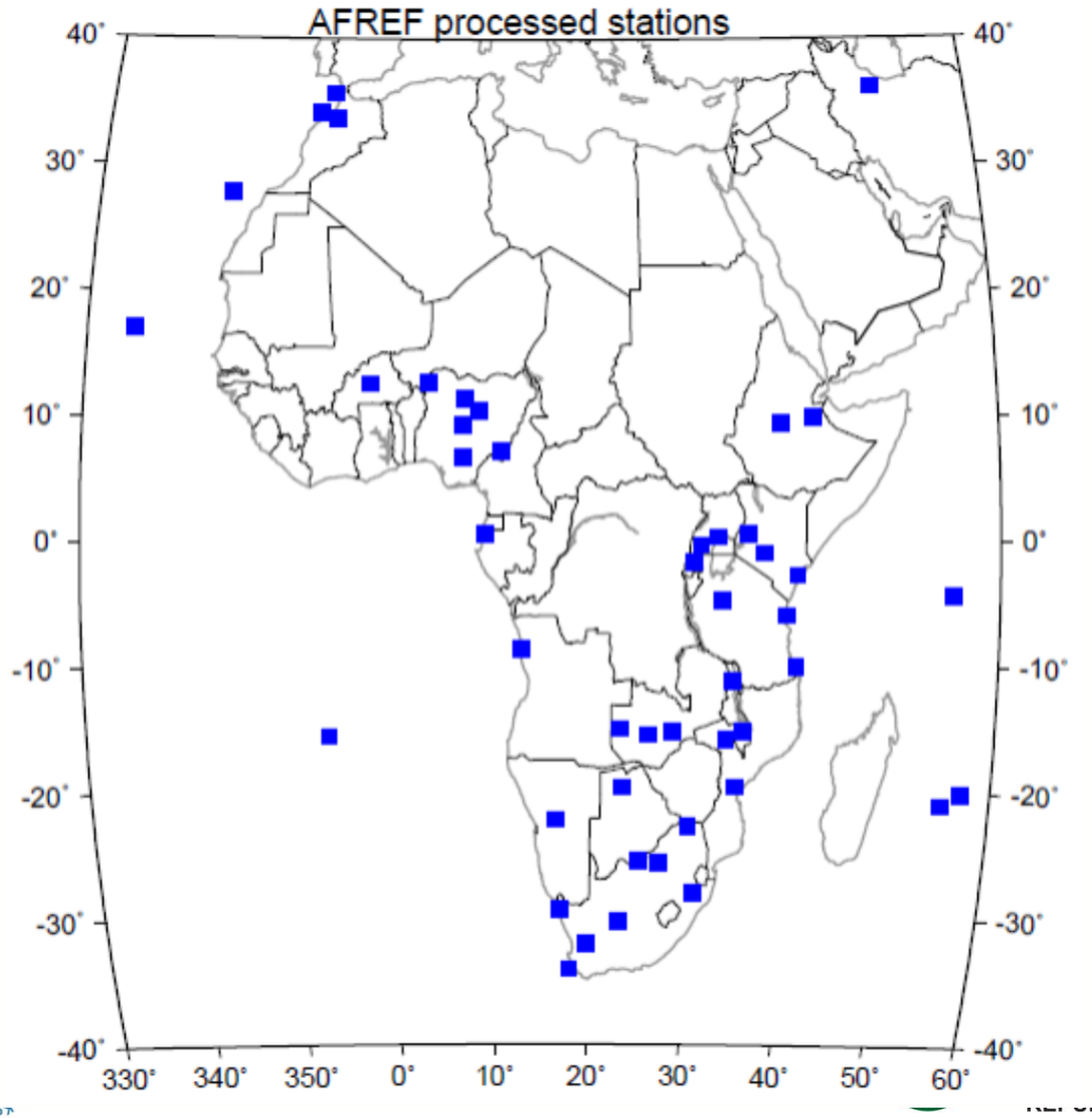
- Denser networks of geodetic stations covering continental areas.
- Eg. African Reference Frame (AFREF), European Terrestrial Reference Frame (EUREF), North American Datum 1983 (NAD83), Sistema de Referencia Geocéntrico para las América (SIRGAS) and the Asia-Pacific Reference Frame (APREF).
- Regional reference frames are defined by the coordinates and site velocities of contributing stations.
- The key difference with some regional reference frames (e.g. EUREF and NAD83) and ITRF is that the site velocities may be with respect to the dominant tectonic plate encompassed by the frame and not a NNR condition.
- This approach minimizes site velocities. Regional frames not constrained by the motion of a single tectonic plate are closely aligned with ITRF.

Regional Reference Frames



African Reference Frame

- First AFREF solution fully connected to ITRF



AFREF

- Most countries in Africa needs roadmap to modern geodetic reference frame.
- The UNGGIM-Africa Working Group on Geodesy will coordinate AFREF activities.
- The success of the new AFREF Project governing structure will depend on support and commitment from of member states, UN organs , scientific associations, FIG and academia.
- SoG Africa members are expected to play a key role as regional coordinators. (Burkina Faso, Cameroon, Côte d'Ivoire, Madagascar, Morocco, Nigeria, South Africa, Tanzania, Tunisia)

National Reference Frames (Geodetic Datums)

- Modern datums are typically a static realization of ITRF or a regional reference frame.
- In most countries the coordinates of a national reference frame (geodetic datum) form the basis for all surveying, positioning and mapping within national borders.
- Because surveying/ GIS software and spatial data are not generally designed to deal with continuously changing coordinates, the epoch for national datums is fixed and the coordinates are considered to be invariant with time (in Southern Africa).

Hartebeesthoek94

- 1 January 1999 ->current day
- Official South African Coordinate Reference System based on the WGS84 ellipsoid and geocentric.
- ITRF91 (epoch 1994.0) co-ordinates of the Hartebeesthoek Radio Astronomy Telescope used as the origin of this system.

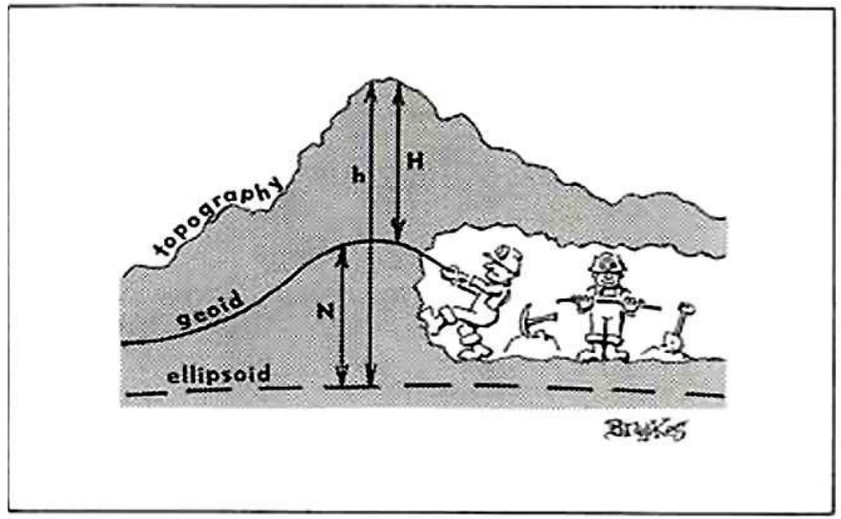
South Africa's current datum (LLD): constraints

Realised from **early-1900s** mean sea level at 4 tide gauges; piecemeal levelling adjustments.

Spheroidal-orthometric height practice (Vignal mean-normal gravity) ≈ normal-orthometric.

Known distortions, MSL instability, and costly maintenance; **inconsistent with GNSS era**.

Modernization requires moving to a gravimetric (quasi)geoid-based vertical datum tied to **IHRS**.



In Search of the Geoid

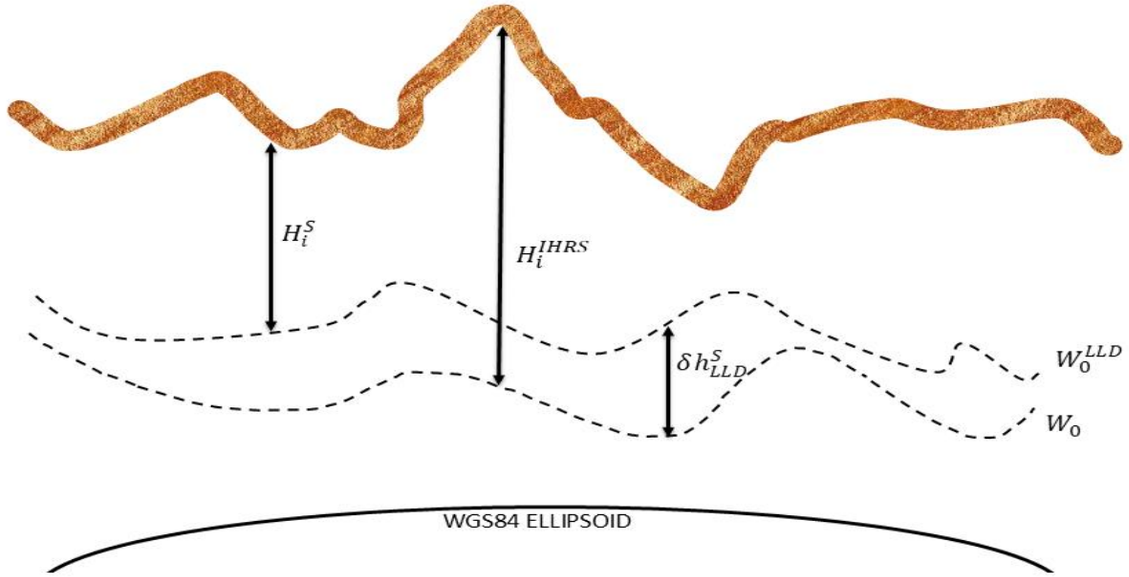
Courtesy of Natural Resources Canada:
www.geod.nrcan.gc.ca/index_e/geodesy_e/geoid03_e.html

Why join the IHRF?

- **IHRF** = globally unified height reference based on a conventional equipotential (W_0).
- **Direct,** GNSS-enabled access to physical heights - no reliance on century-old tide gauges.
- Consistency across borders and projects; easier datum maintenance and updates.
- Supports sea-level, infrastructure, flood risk, and geodynamics applications.

Path to an IHRF-aligned, geoid-consistent datum

Adopt the IHRF framework: estimate LLD zero-level geopotential W_0^{LLD} and offset ΔW to IHRF (W_0).



*Conceptual diagram of height transformation between **LLD** and **IHRF** via the offset* $\boldsymbol{\delta h_{LLD}^S}$

Implementation roadmap (South Africa)

- **Policy**: formal decision on height system and IHRS adoption; governance & timelines.
- **Data**: GNSS/levelling re-validation; gravity densification; airborne/terrestrial gravity where sparse.
- **Model**: compute national gravimetric quasigeoid/geoid; validate vs benchmarks; uncertainty budget.
- **Unification**: adopt ΔW and δh; provide national conversion tools & EPSG codes.
- **Operations**: publish guidance, training, and change-management with stakeholders (NGI, SAGI, municipalities).


THANK YOU