GGCE Capacity Development Workshop for Europe – 2025

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IGN
INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

RÉPUBLIQUE FRANÇAISE
Liberté Égalité Fraternité

CNIG
Conseil national de l'information géolocalisée

Workshop menu

The importance of GRS
Introduction to GRS Infrastructure
Aligning national geodetic datums to ITRF
ETRS89 - Introduction - Realization - Limitations
Introducing regional collaboration in geodesy
What is a geodetic adjustment
How to undertake a national geodetic adjustment
Introduction to standardisation in geodesy
Tools for standardisation
Data registers and data sharing policies
Development of transformation parameters
Example - Creating transformation parameters
Height Datums and Geoid Models
Steps in Geoid Modelling

Identifying Capacity Development needs & Country Cases
International Geodesy initiatives and partners
UN-GGCE Update
Communications
WHAT Developing business cases & Group Activity
Governance
Forward looking Future Directions for Geodesy
HPC&AI

Material available on
https://ggim.un.org/UNGGCE/#capacity-development

UNITED NATIONS GLOBAL GEODETIC CENTRE OF EXCELLENCE : team

- https://ggim.un.org/UNGGCE/

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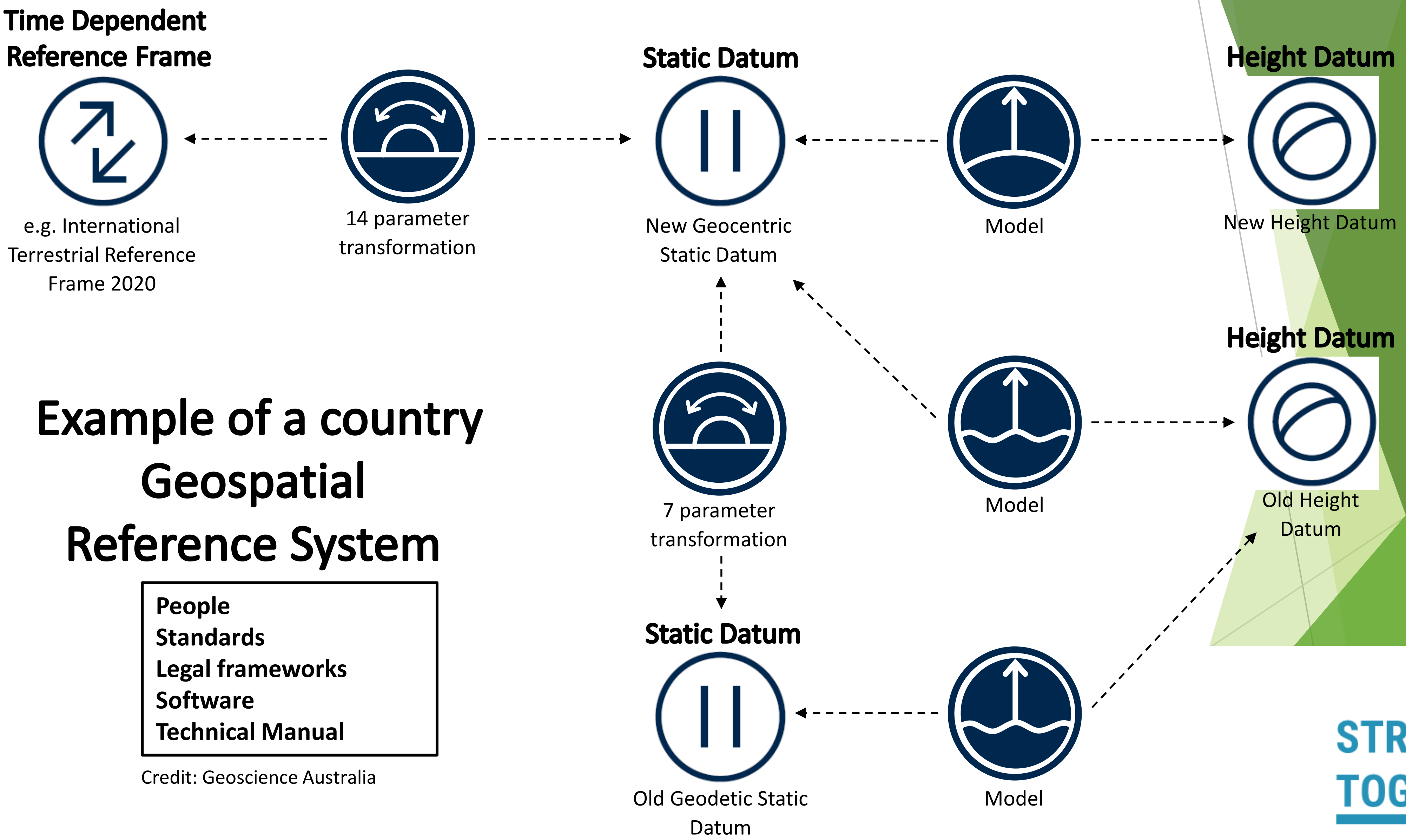
Geospatial Reference System



Example of a country Geospatial Reference System

People
Standards
Legal frameworks
Software
Technical Manual

Credit: Geoscience Australia

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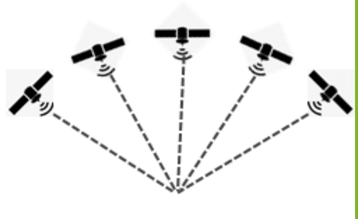
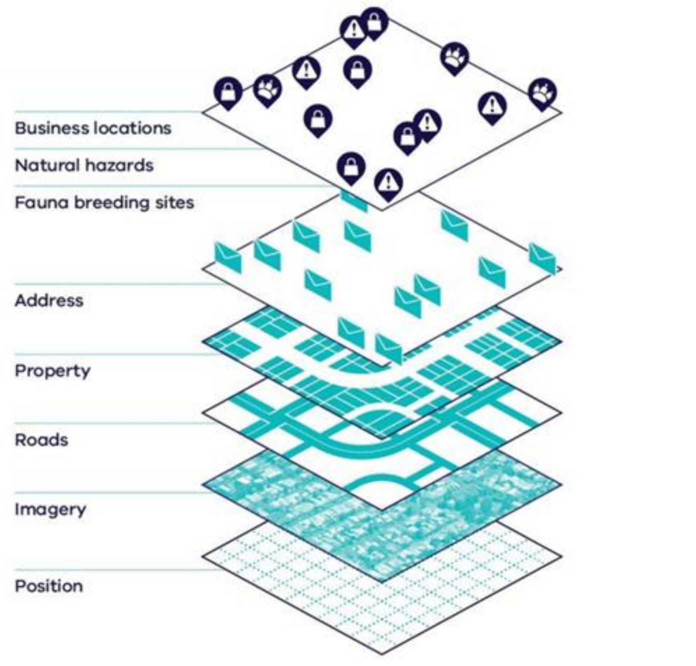
Why is a GRS important?

- A Geospatial Reference System underpins the collection, management and alignment of spatial information to make better decisions.
  - survey, mapping and navigation;
  - civil engineering, industrial automation, agriculture, construction, mining;
  - recreation; location-based services;
  - intelligent transport systems, land use planning and administration;
  - hazard assessment, disaster response and emergency management;
  - environmental studies and scientific research.
- The Geospatial Reference System is the **glue** that allows us to align all geospatial data.
- The importance of Geospatial Reference Systems was recognised by the United Nations in 2015 with the adoption of a General Assembly Resolution promoting the importance of an *accurate, sustainable and accessible Global Geodetic Reference Frame to support science and society*.





Credit: Victorian State Government, Australia

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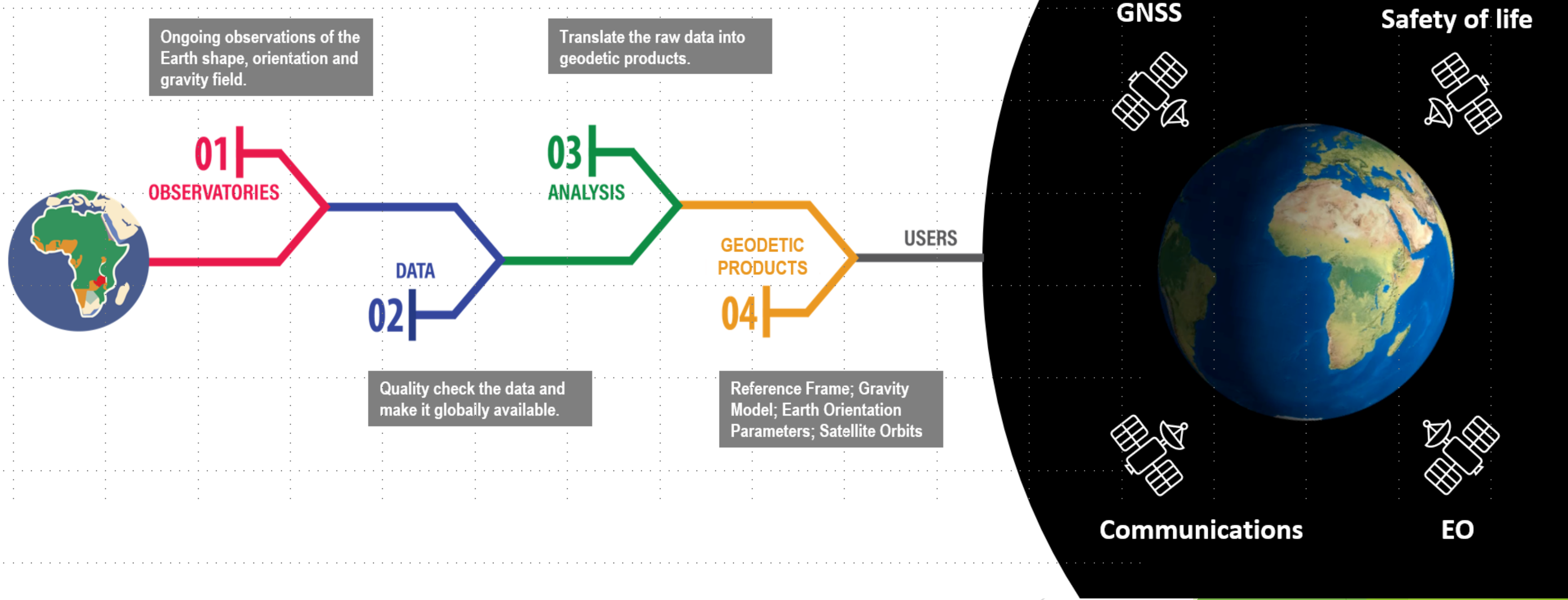
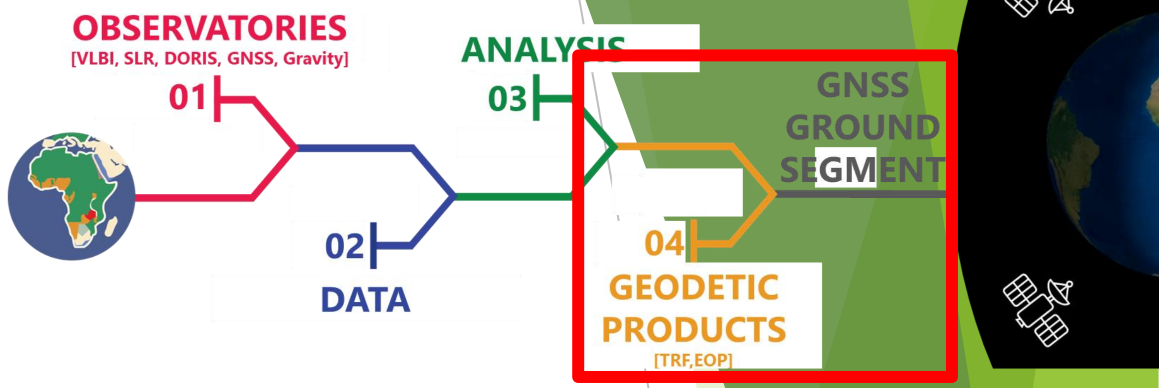
Global Geodesy Supply Chain



GNSS Ground Segment



GNSS Ground Segment

- Monitor GNSS satellites (position, health, status)
- Command and Control
  - Updating ephemeris (every few hours)
    - GNSS Ground Control Stations use Earth Orientation Parameters to accurately calculate the positions and orbits of GNSS satellites and the timing corrections applied before the ephemeris is uploaded to the satellites.
    - Since the Earth's orientation and rotation can change slightly over time, EOPs are critical to ensure satellite positions are calculated with high precision relative to a fixed reference frame (Terrestrial Reference Frame (TRF)).

    - **Dependencies:** Terrestrial Reference Frame and Earth Orientation Parameters

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Are the geodetic products robust?

- Terrestrial Reference Frame
- **Earth Orientation Parameters**
  - Precession and Nutation – highly predictable – low concern
  - Length of Day – dynamic – medium concern
  - Polar motion – dynamic – medium concern
  - UT1-UTC – dynamic – high concern

** It is debatable how often these parameters need to be updated before causing a loss of accuracy or reliability in satellite services, however, even if it is three years before problems occur, VLBI, SLR and DORIS are needed.*

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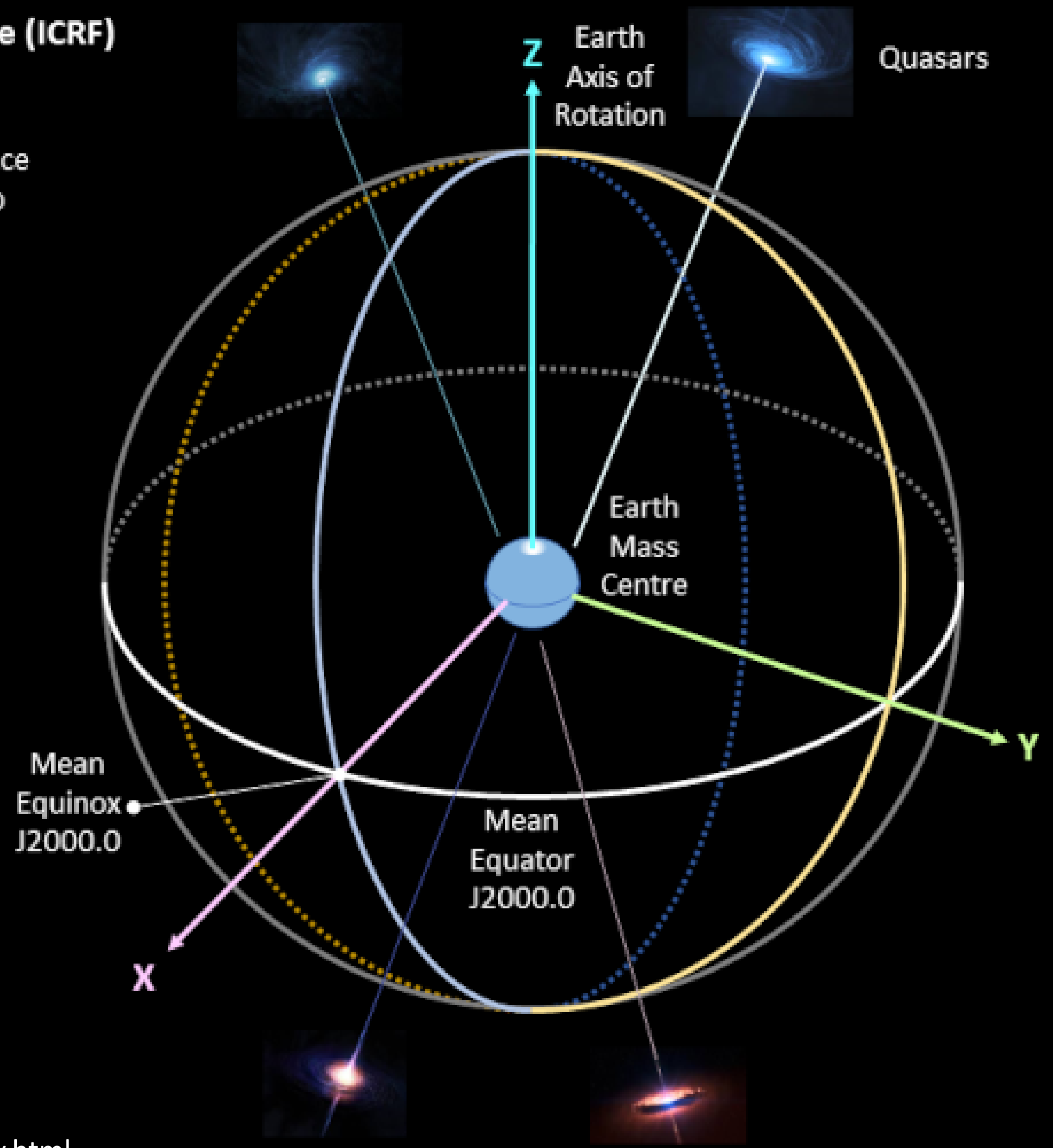
International Celestial Reference Frame (ICRF)

International Celestial Reference Frame (ICRF)

The International Earth Rotation and Reference Systems Service (IERS) was created in 1988 to establish and maintain a Celestial Reference Frame, the ICRF. The ICRF is defined by the position of significant celestial objects. Perhaps the most important of these are the so called radio-loud quasars. These are super massive black holes at the centre of galaxies that radiate huge amounts of energy. A quasar typically emits radiation with a unique signature - a pattern across the radiation spectrum. These quasars, to all intents and purposes, appear as fixed points in the sky and thus as fixed reference points in the ICRF.

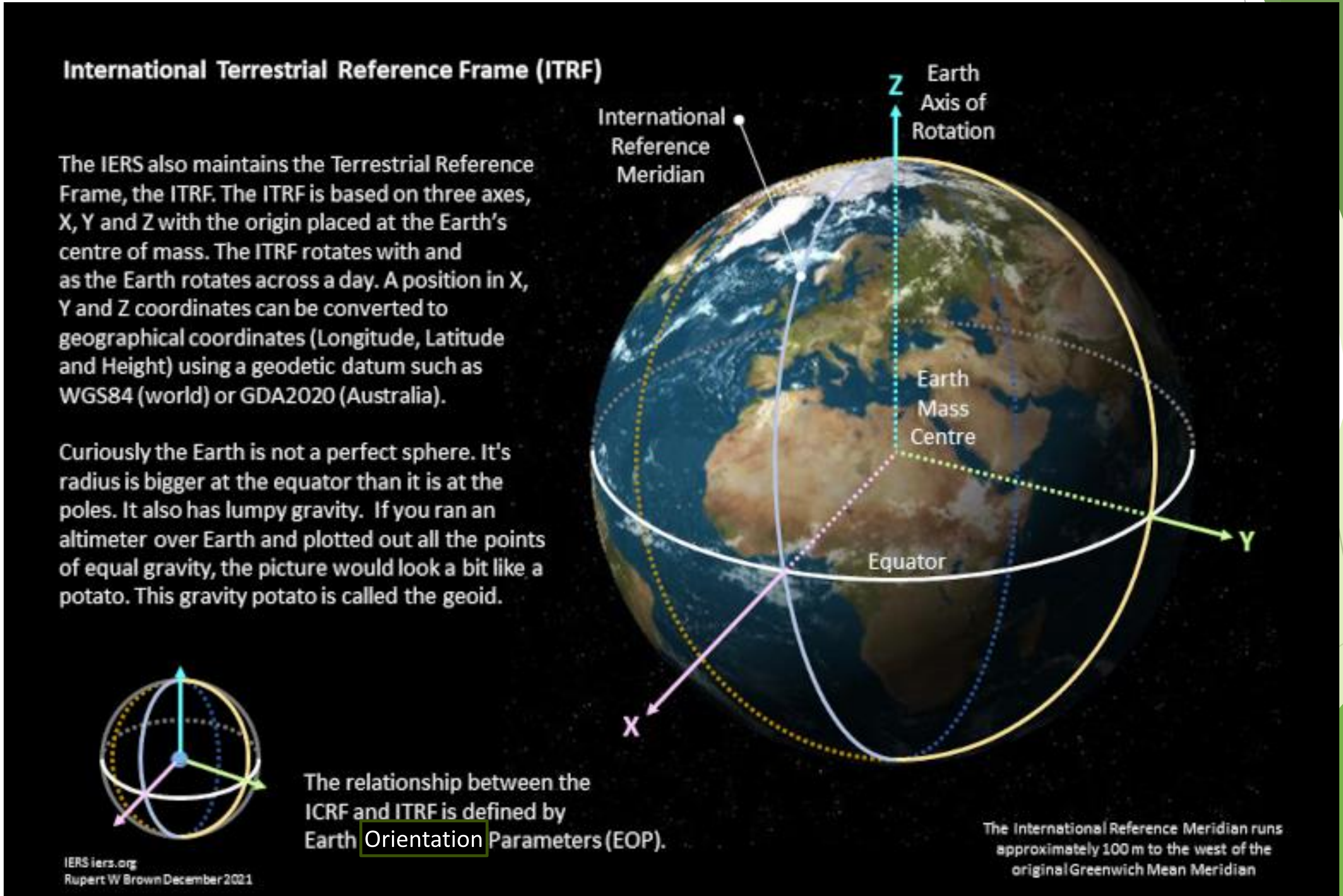


J2000.0 is a standard Julian equinox and epoch - January 1, 2000 at 12:00 TT.

IERS iers.org
Rupert W Brown September 2021

https://geoscienceaustralia.github.io/ginan/theory.html

International Terrestrial Reference Frame (ITRF)

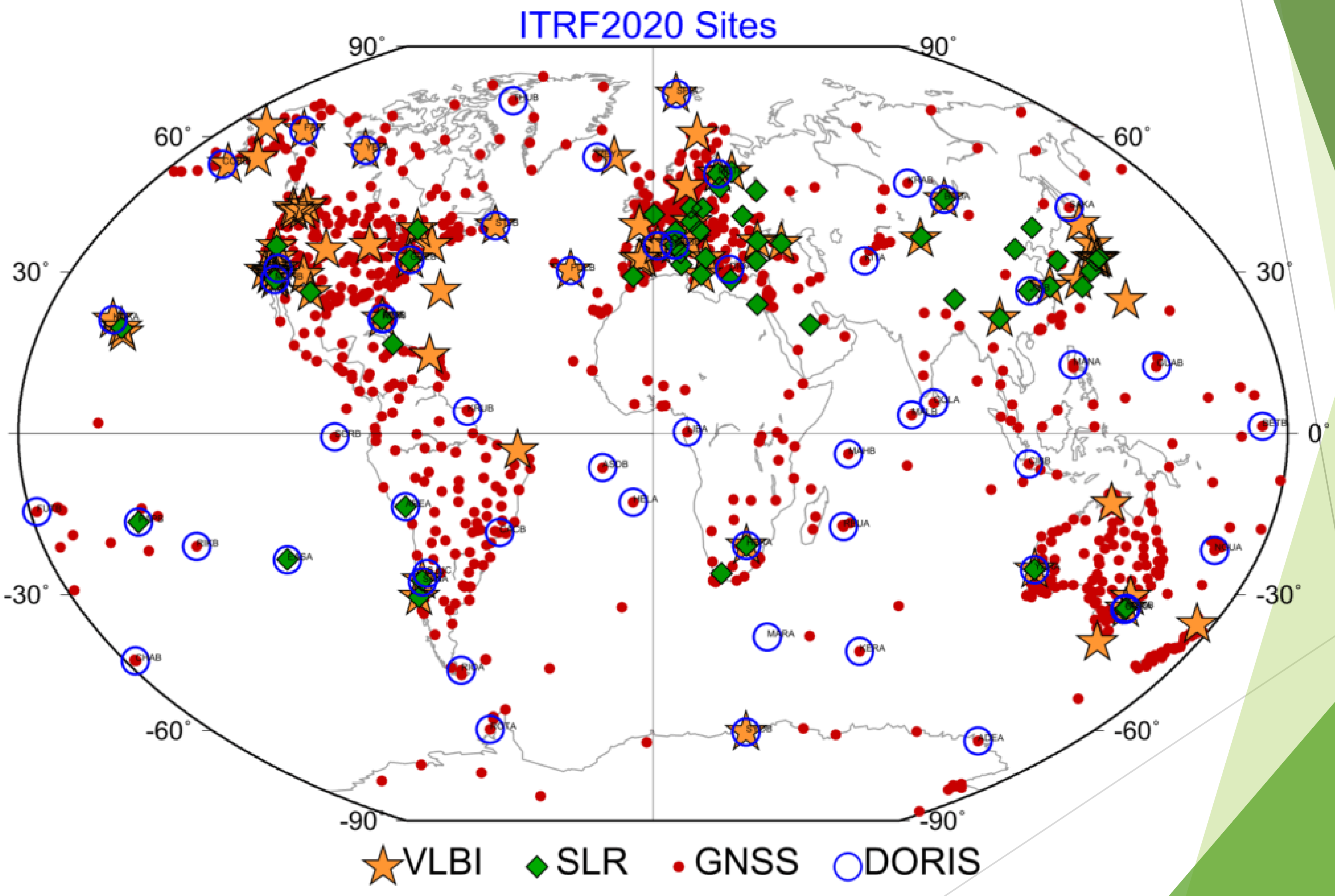


https://geoscienceaustralia.github.io/ginan/theory.html

ITRF Observation Techniques

VLBI

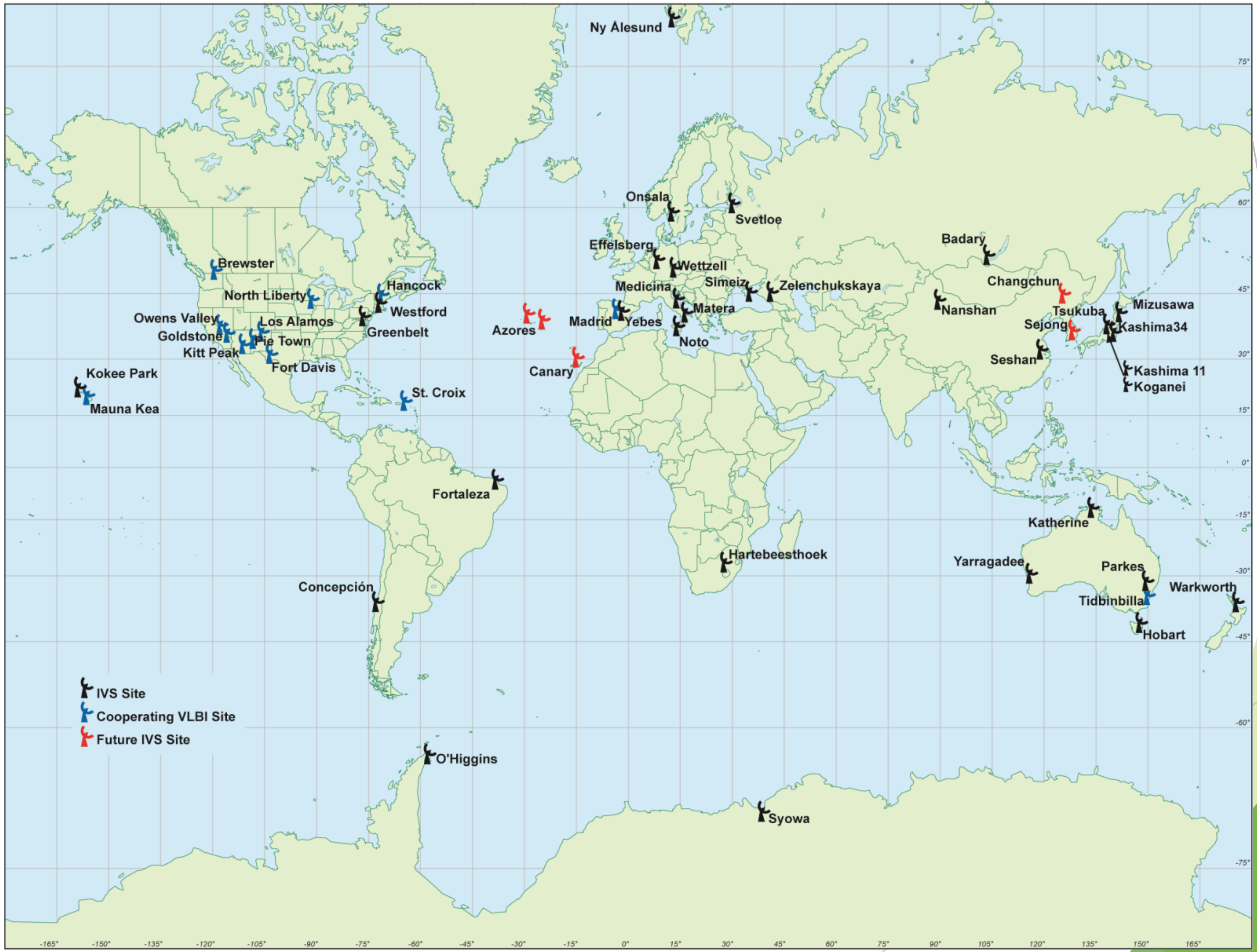
SLR



GNSS

DORIS

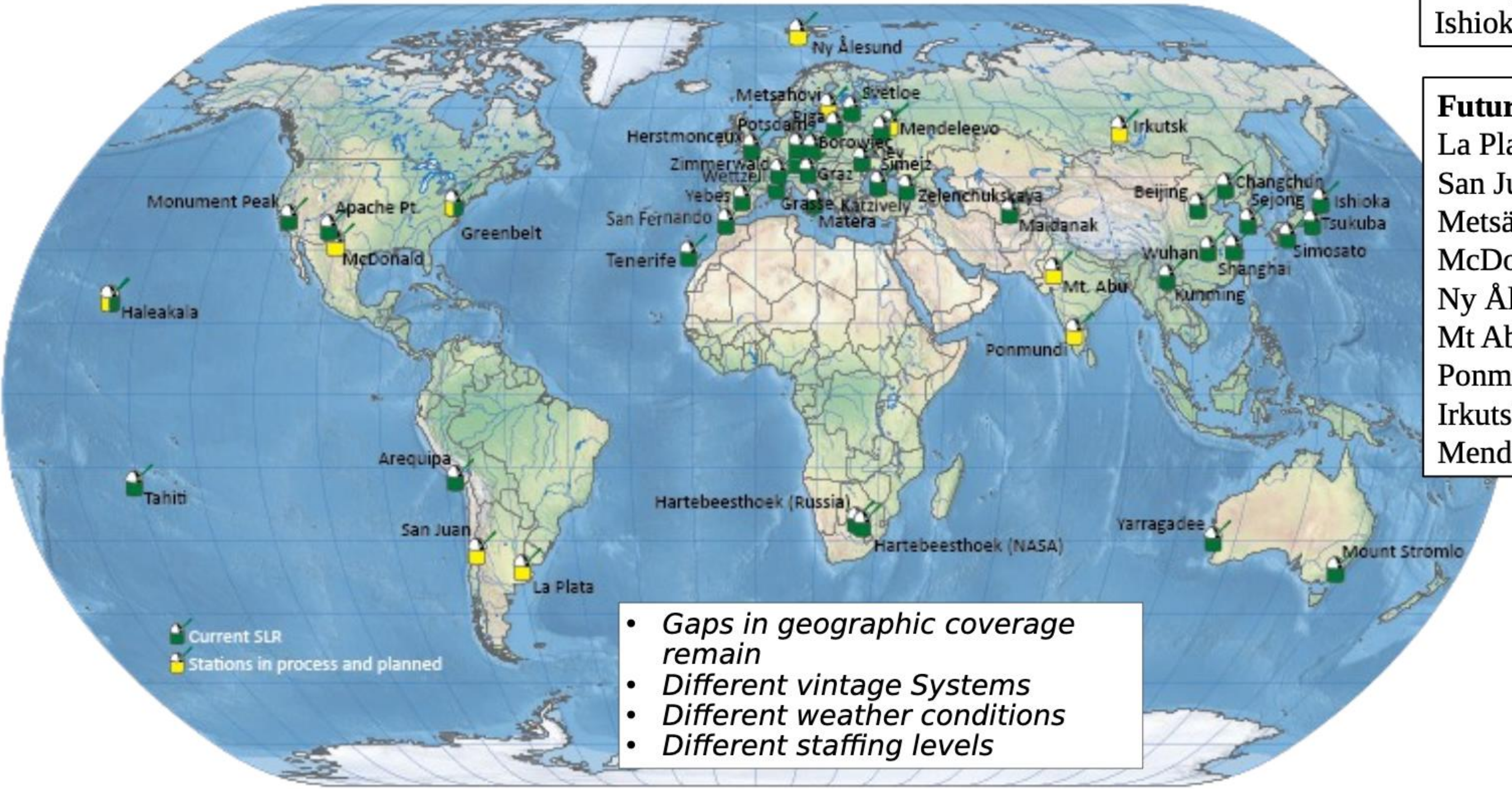
International VLBI Service for Geodesy and Astrometry



(source: ivscc.gsfc.nasa.gov)

International Laser Ranging Service

Current and Planned ILRS Network



- *Gaps in geographic coverage remain*
- *Different vintage Systems*
- *Different weather conditions*
- *Different staffing levels*

New Stations (2023-2024)
Yebes, Spain
Ishioka, Japan

Future Stations (2024-2027)
La Plata, Argentina
San Juan, Argentina
Metsähovi, Finland
McDonald, TX, USA
Ny Ålesund, Norway
Mt Abu, India
Ponmundi, India
Irkutsk (Tochka), Russia
Mendeleevo (Tochka), Russia

source: ilrs.gsfc.nasa.gov

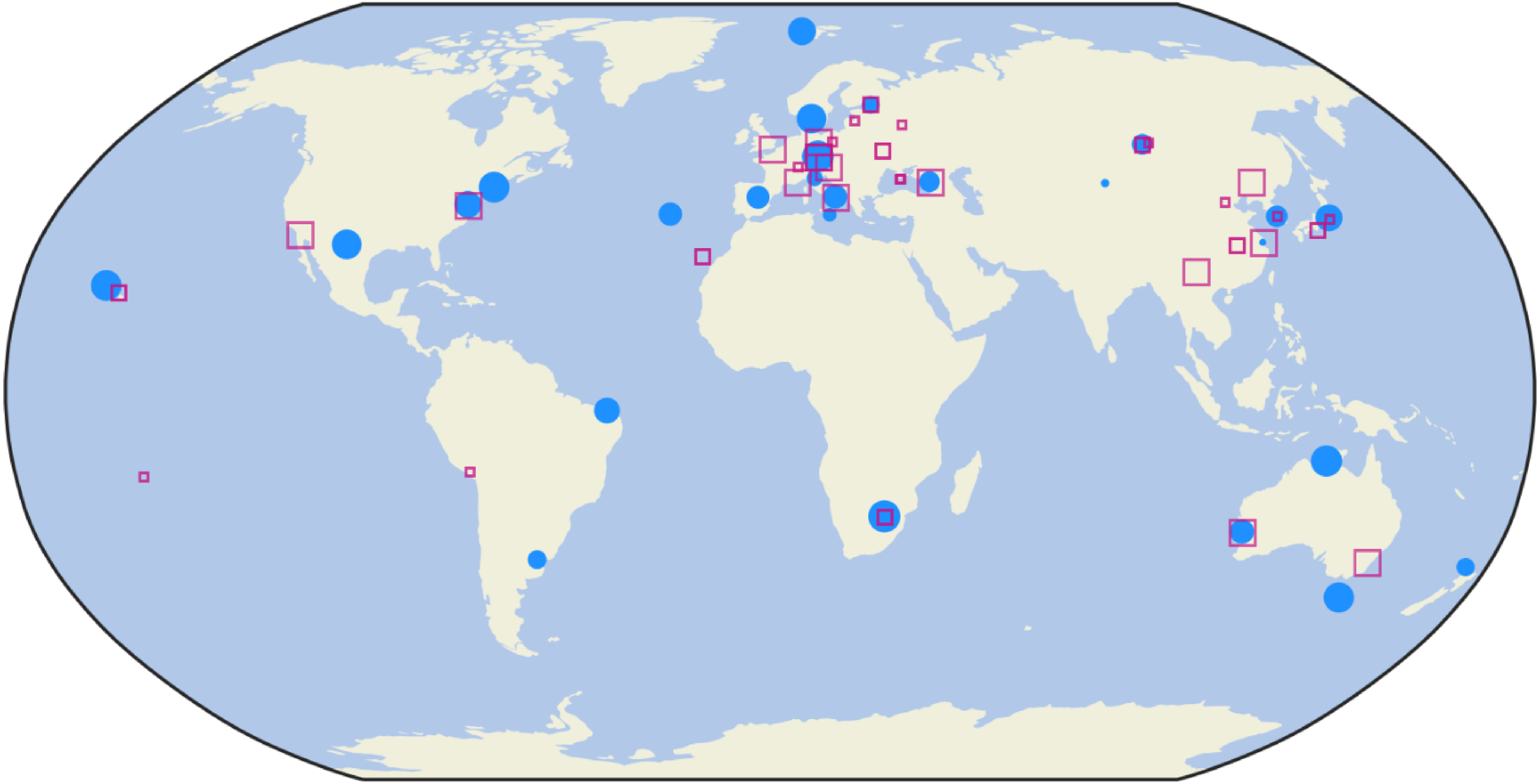
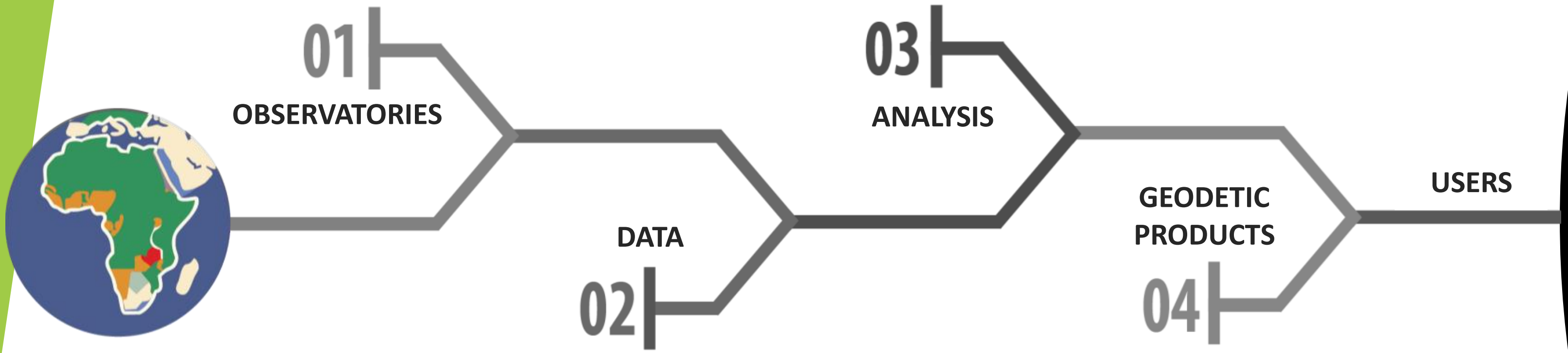


Figure: ***Locations of ground-bas VLBI LBI stations; SLR d SLR stations. The size of the circles and squares are roughly proportional to how much data each station provides to the global geodesy supply chain. The data is from 2023-2024.***

Weaknesses in the Global Geodesy Supply Chain

EVIDENCE

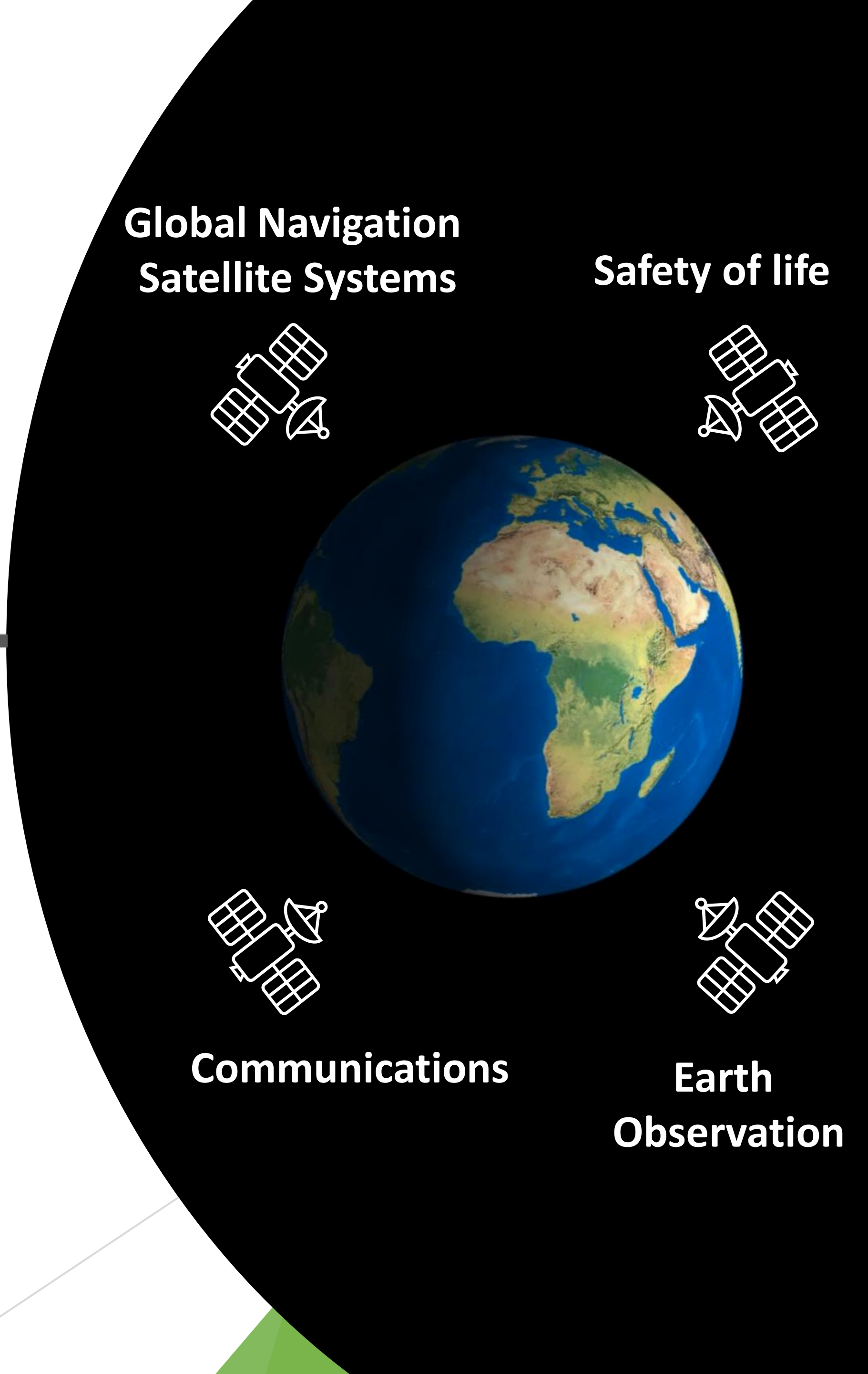
RESOURCES



AWARENESS

CAPACITY

GOVERNANCE



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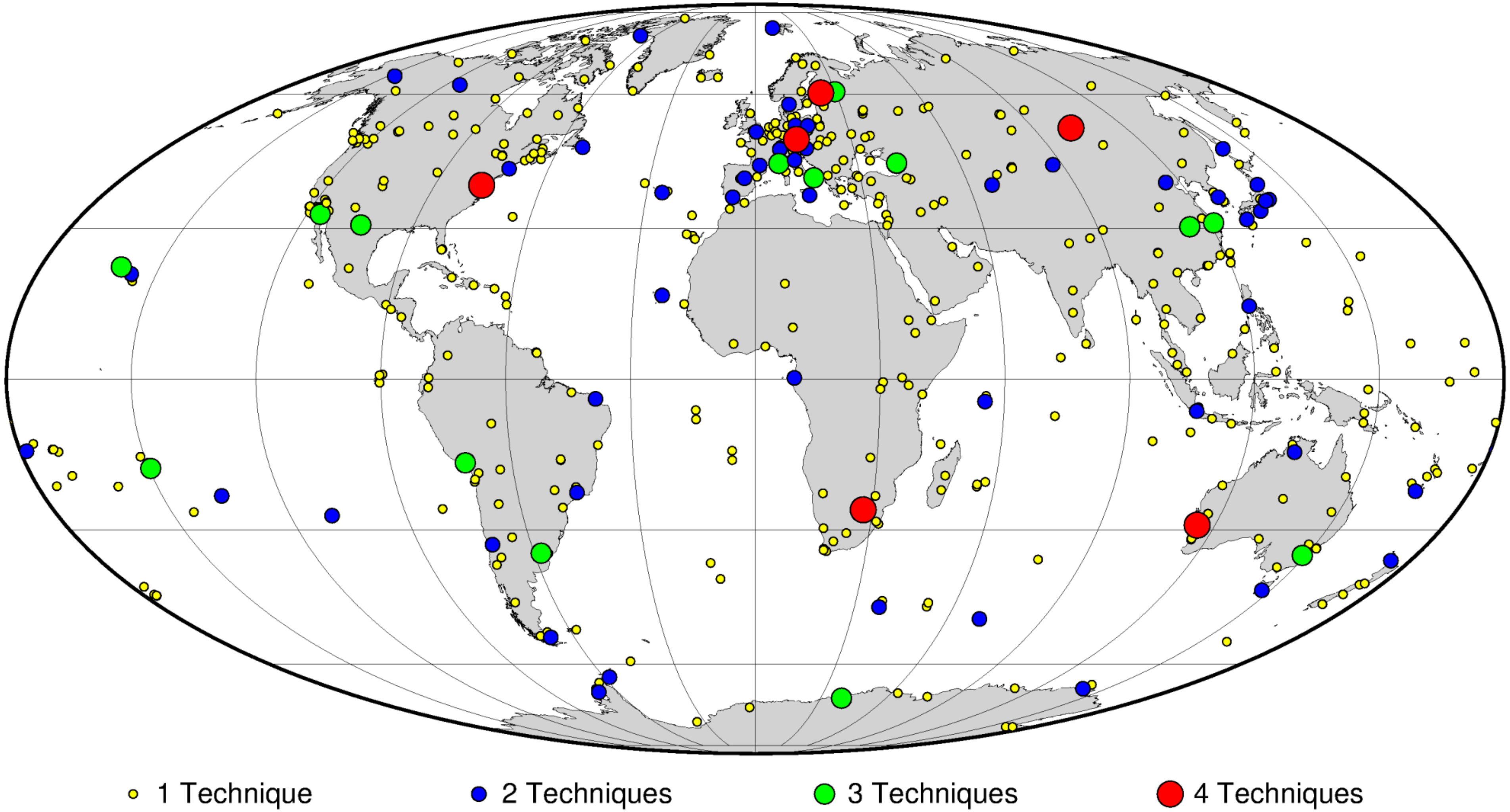
Collocation of the techniques

ITRF: International Terrestrial Reference Frame



- Only one continent has at least three sites where VLBI and SLR are collocated.
- **The global geodesy supply chain is not robust.**

Equations à résoudre à propos de la chaîne d’approvisionnement géodésique mondiale

- **Robustesse et redondance** des observatoires/centres d’analyse/centres de stockage (serveurs)
  - Un seul serveur (CDDIS) pour les données des 4 techniques de géodésie spatiale
  - Y a-t-il un plan B? La réponse est souvent “non”
  - Grande dépendance envers les USA aujourd’hui
- **Combien** faut-il **de stations colocalisées VLBI - SLR/LLR - GNSS dans le monde** pour assurer la fourniture des EOP suffisamment précis et fiables pour garantir les besoins actuels en positionnement GNSS (en particulier temps réel)?
  - À la louche: 3 sites colocalisés par continent, avec une distribution optimale
  - Manque de publication et preuves scientifiques pour étayer cette affirmation (difficultés pour quantifier l’instrumentation supplémentaire requise pour avoir quelque chose de suffisamment robuste)
- **Si le réseau géodésique mondial actuel se dégrade, quelles seront les conséquences sur le positionnement GNSS**
  - Ordre de grandeur de la dégradation?
  - Au bout de combine de temps?

REGIONAL REFERENCE FRAMES

- EUREF and ETRS

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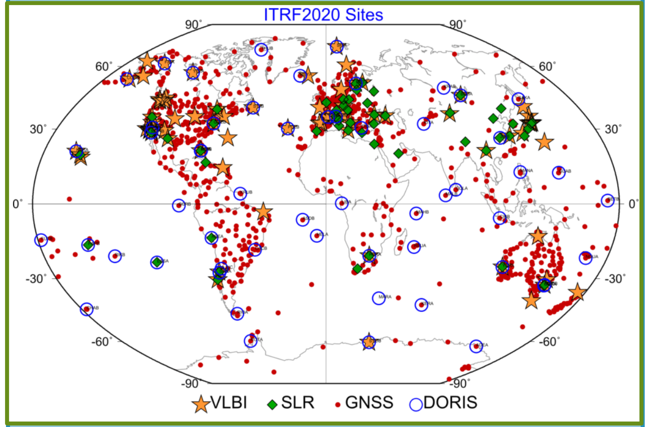
Motivation

Aligned

Global



International Terrestrial Reference Frame

Time dependent

Aligned

Regional (Europe)

Regional
Continental plate

Static / Time dependent

Aligned

National (Germany)

Static / Time Dependent

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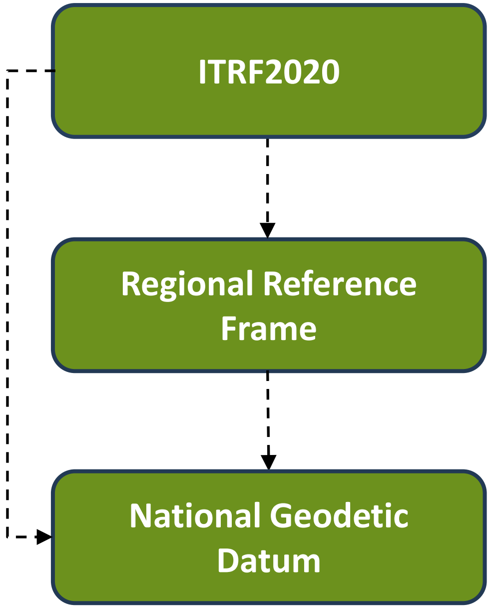
How to align a National Geodetic Datum with ITRF



1. Choose an ITRF realisation and epoch to align to (e.g. ITRF2020@2024)

2. Include the GNSS CORS from your country in the regional reference frame (if possible)(e.g EUREF)

3. The positions from the GNSS CORS in your country which are analysed in the regional reference frame are used as the constraint in the national adjustment.

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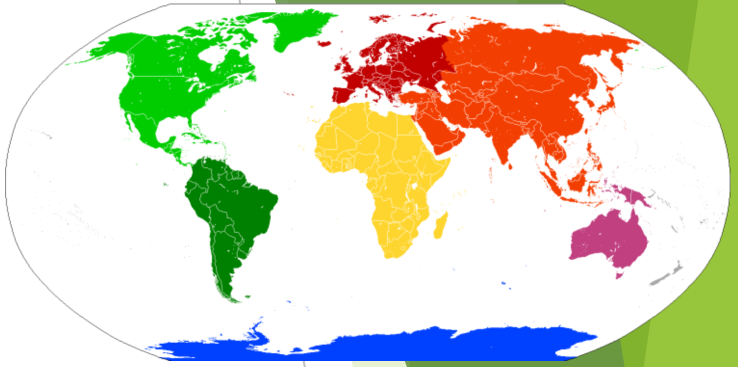
Motivation for regional collaboration

- Continental densification of the International Terrestrial Reference frame (ITRF)
  - The realization of ITRF has to restrict the number of GNSS sites for computational reasons
  - The purpose of ITRF is to determine an accurate global model (not monitor geophysical processes)
- The basis for national geodetic datum development
- More detailed monitoring of continental stability
- Geo-referencing and positioning applications, e.g cadaster, land administration, …
- Basis for monitoring of regional deformations
- Unification of geodetic and mapping applications within a continent or a region



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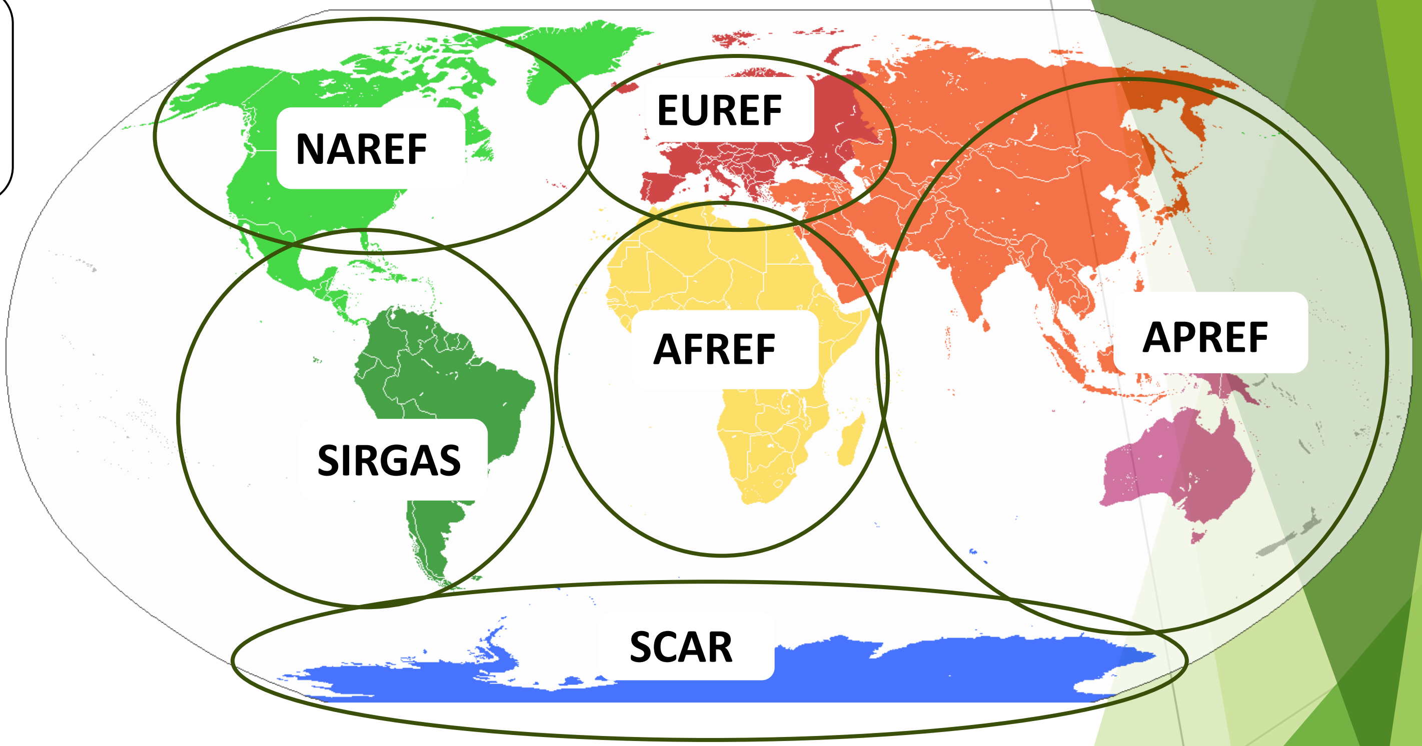
ITRF and regional networks

International Association of Geodesy (IAG)
Operation of ITRF

IAG Commission 1
Reference Frames

Sub-commission 1.3
Regional Reference Frames



EUREF 1.3a Europe	**SIRGAS** 1.3b South America	**NAREF** 1.3c North America	**AFREF** 1.3d Africa	**APREF** 1.3e Asia Pacific	**SCAR** 1.3f Antarctic

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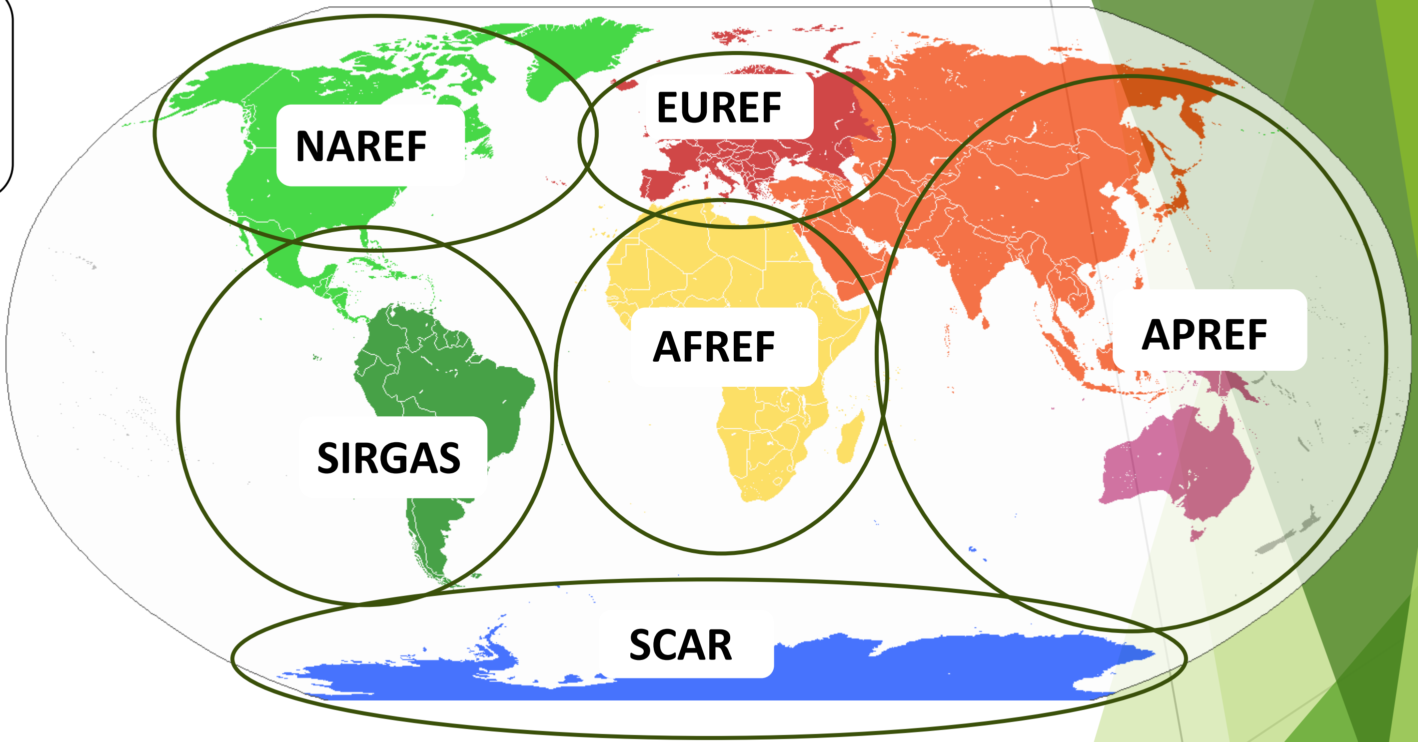

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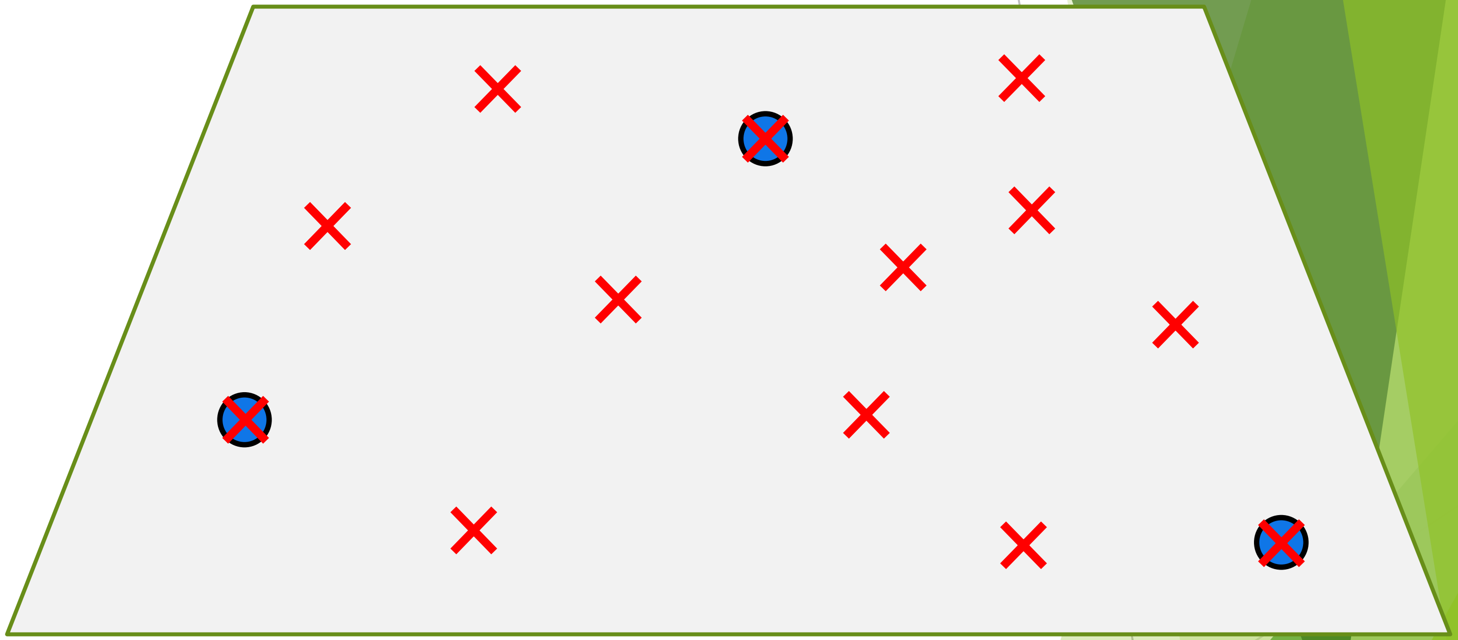
How to align a National Geodetic Datum with ITRF

- ✕ - GNSS CORS
- ● - GNSS CORS included in regional reference frame



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NORMES

- ISO & Co

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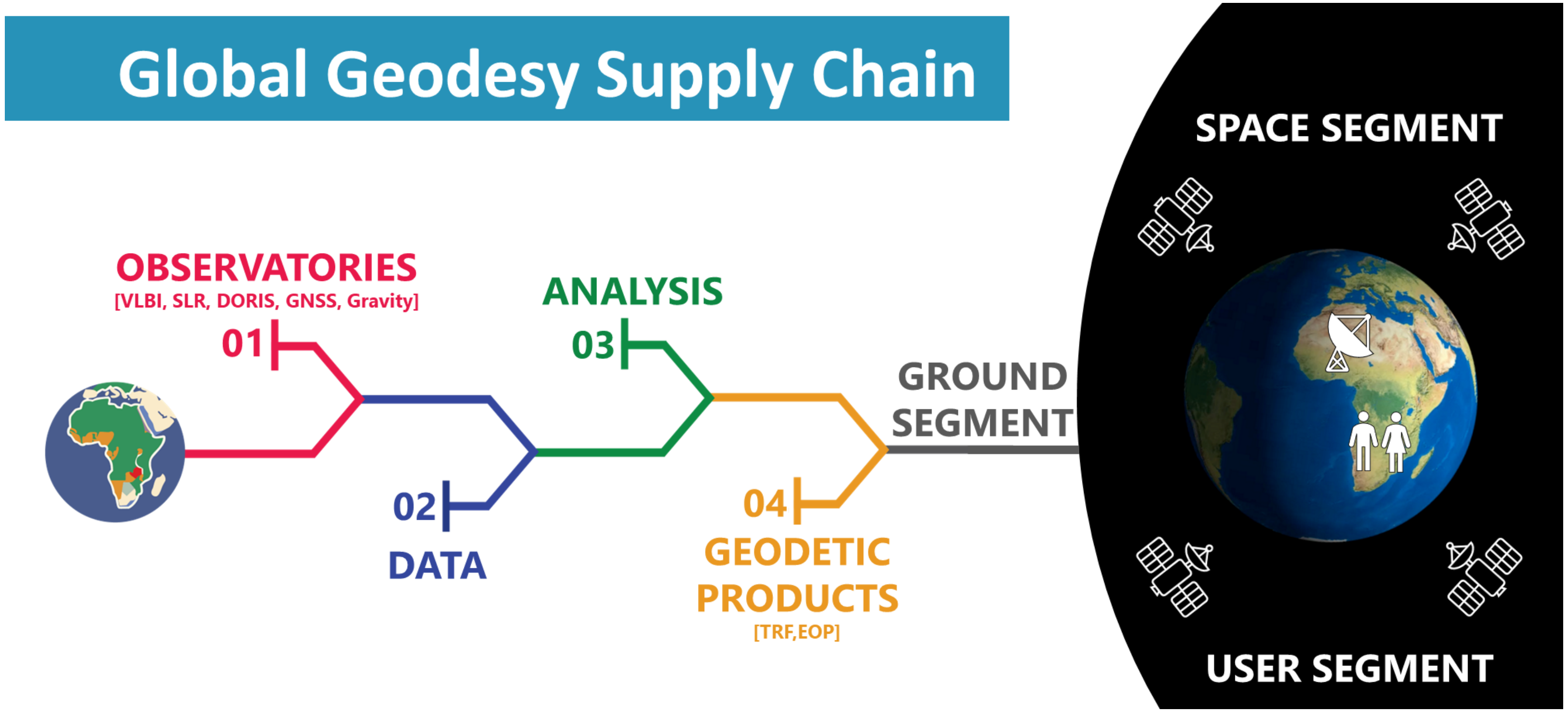
Why do we need standards in geodesy?



- **Consistency** of raw observations from various ground and space-based stations
- **Consistency** of analysed data and geodetic products
- Observations and data **quality assurance**
- **Interoperability** of different geodetic techniques
- **Compatibility** of geodetic data with another geospatial information systems
- **Seamless access** to geodetic products for users

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OUTLINE

1. Introduction and key definitions
2. **ISO standards**
   - **2.1 What is ISO?**
   - **2.2 Geographic locations and coordinates** (ISO 6709, ISO 19111, ISO 19161)
   - **2.4 Metadata** (ISO 19115)
   - **2.5 Data registry** (ISO 19127, ISO 19135)
3. OGC standards
4. Other standardisation practices
5. Summary and conclusions

ISO 19161-1, 19161-2 for ITRS and ground stations identification

ISO 19161-1:2020 "Geographic information – Geodetic references – Part 1: International terrestrial reference system (ITRS)", https://www.iso.org/standard/70655.html.

- Sets standards on how to "realise" the ITRS according to different categories (e.g., general, primary, secondary) and intended purposes.

(under development, approved)
ISO 19161-2 "Geographic information – Geodetic references – Part 2: Unique identification of geodetic ground stations", https://www.iso.org/standard/89134.html#lifecycle.

- Modernises the method for unique identification of ground geodetic stations by replacing the existing Directory Of MERIT[1] Sites (DOMES) numbering system.
- Contributes to interoperability among various Global Navigation Satellite Systems (GNSS).
- Supports the United Nations Global Geospatial Information Management (UN-GGIM) actions on global geodetic reference frame.

DOMES number[2]: **10002M006**

- The first 3 digits indicate the area, usually the country **100=France**
- The next 2 digits indicate the site number within the country **02=Grasse**
- The next letter indicates the tracking point **"M" for monuments**
- the last 3 digits represent a sequential point number **006 is GPS Pillar/brass mark**

1. MERIT – an international program to Monitor Earth Rotation and Intercompare the Techniques (MERIT) of observation and analysis. For further details see
   - Wilkins, G. A., and I. I. Mueller (1986), Rotation of the Earth and the Terrestrial Reference System, Eos Trans. AGU, 67(31), 601-605, doi:10.1029/EO067i031p00601.
   - Wilkins, G.A., Mueller, I.I. (1986), On the rotation of the Earth and the terrestrial reference system. Bull. Géodésique 60, 85-100, https://doi.org/10.1007/BF02519356.
2. ITRF. "Description of the DOMES Numbering System." ITRF Network, https://itrf.ign.fr/en/network/domes/description. Accessed January 26, 2025.

Intelligence artificielle

- Dall-E 3:
  - Show me an image of an accomplished geodesist who finished all work towards a sustainable global geodetic reference frame.
    - Image courtesy of Ingrid van Berge / Jeremy Verbeurgt

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Computing transformation parameters

WGS72			ITRF2005@2008		
X	Y	Z	X	Y	Z
-6090790.9	-128354.37	-1882866.9	-6090792	-128369.45	-1882863.4
-6045005.5	248397.533	-2012568.4	-6045006.5	248381.197	-2012567.1
-6025612.8	211678.93	-2075994.5	-6025613.9	211663.535	-2075992.1
-6128128.4	-876.912	-1763105.8	-6128129.1	-891.7874	-1763104.9
-6125126.2	96614.615	-1770429.2	-6125127.8	96598.2963	-1770426
-6026782	26320.369	-2081724.6	-6026782.9	26305.2446	-2081722.5
-6069393.3	74317.387	-1952868.1	-6069393.4	74300.7507	-1952865.8
-6023321.1	-167612.93	-2084345.8	-6023324.4	-167626.93	-2084343.3
-5969814.4	-131365.08	-2234500.4	-5969817.8	-131380.6	-2234496.5
-6108964.6	182329.478	-1818369.1	-6108966.7	182311.746	-1818366.9
-6106871.3	158749.826	-1828962.4	-6106871.9	158732.376	-1828960.6
-6219742.5	324299.487	-1371185.6	-6219743.2	324285.601	-1371182.7
-6101703.1	8543.67	-1852334.1	-6101703	8527.7474	-1852331.8
-6060199.7	-129057.38	-1978129.3	-6060202.2	-129071.48	-1978127.2
-6078940	247719.845	-1908646.9	-6078942.2	247703.336	-1908644.9
-5999583.7	-183087.63	-2149906.5	-5999585.5	-183103.61	-2149904.6

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Computing transformation parameters

AI results

Translations (meters):

Tx= -6.9344
Ty= -21.2037
Tz= -10.4443

Scale factor (unitless):

S= -1.42 ppm

Rotations (arcseconds):

Rx= -0.1225
Ry= 0.3425
Rz= -0.2289

Dawson and Hu results

Translations (meters):

Tx= -7.0295
Ty= -22.1185
Tz= -10.1505

Scale factor (unitless):

s= -1.4227 ppm

Rotations (arcseconds):

Rx= -0.1139
Ry= +0.3325
Rz= -0.2573

ChatGPT RMSE residuals

X: 0.887 m
Y: 1.038 m
Z: 0.745 m

Dawson and Hu RMSE residuals

X: 0.983 m
Y: 0.863 m
Z: 0.808 m

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Interface terre-mer

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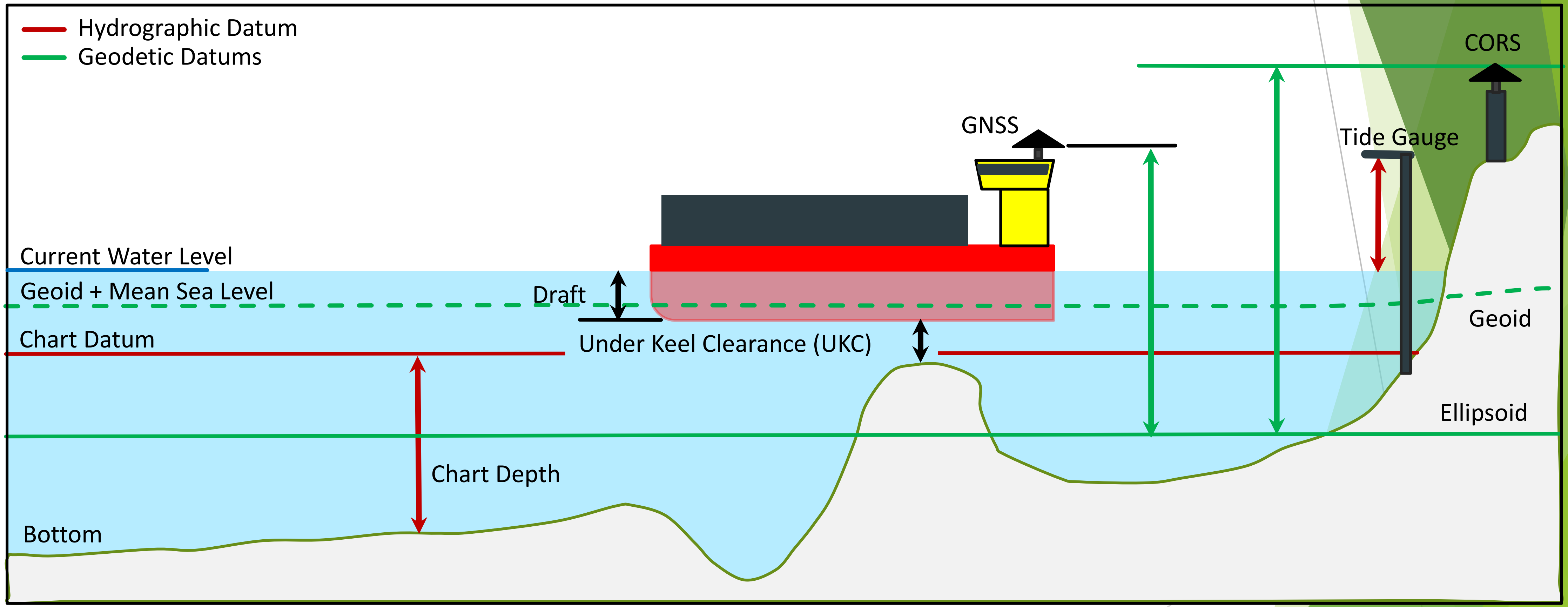
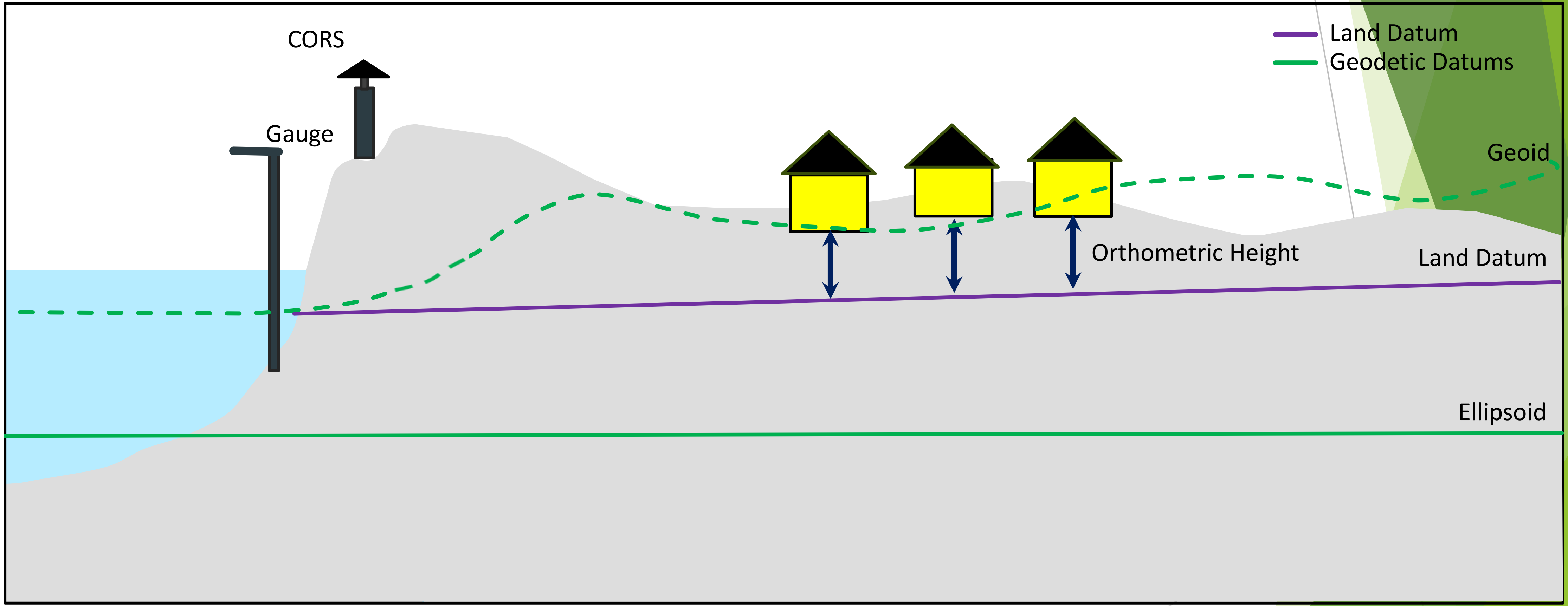
The Sea



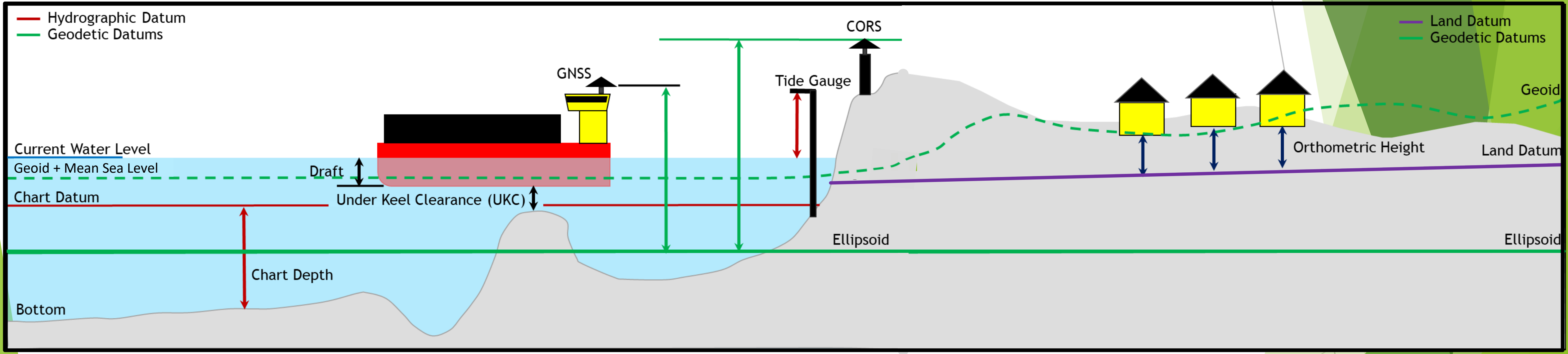
Hydrographic Datum
Geodetic Datums
CORS
GNSS
Tide Gauge
Current Water Level
Geoid + Mean Sea Level
Draft
Chart Datum
Under Keel Clearance (UKC)
Geoid
Ellipsoid
Chart Depth
Bottom

The Land



CORS
Gauge
Land Datum
Geodetic Datums
Geoid
Orthometric Height
Land Datum
Ellipsoid

Joining Land and Sea using geodesy



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CAPACITY DEVELOPMENT

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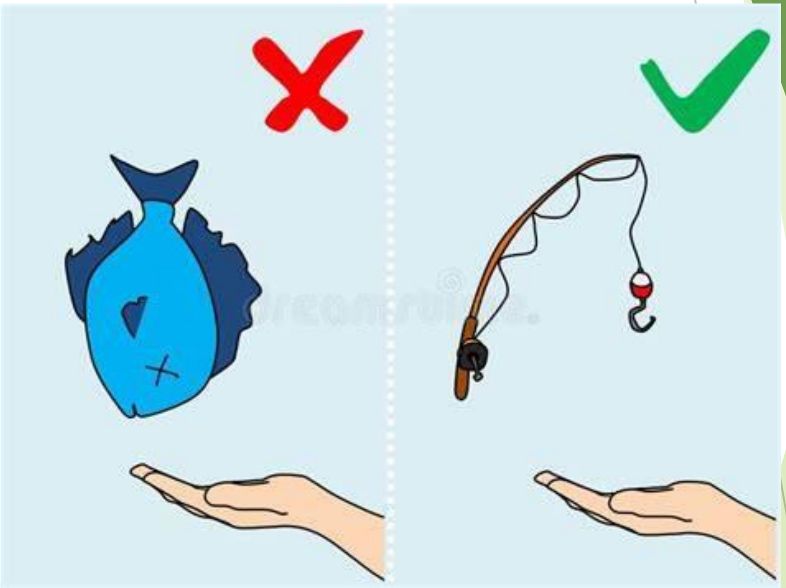
Capacity Development - What and Why?

What is it? It is Assistance (formal and/or informal) comprising….

- Resources
  - Human
  - Fiscal
  - Equipment
  - Expertise
  - Data
  - Policy
  - Time



Why is it needed?

- Because an 'organisation' may not possess a sufficient amount of resources (or capabilities) to do it alone
  - It can also be stated as 'lack of capacity'
- Because groups wish to learn, network and collaborate

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Capacity Development - How and Who starts?

It depends ....

- Organisations requiring it, can request it
- Those with the spare capacity, can offer it to the community

=> Often summarised as:

- CD (Capacity Development)
- ETCB (Education, Training and Capacity Building)

Forms of Capacity Development Resources

- **Human** - experts providing assistance and support, training
- **Fiscal** - funding to procure, operate, maintain, upgrade
- **Equipment** - new, used, configurations, pool
- **Expertise** - training; in-field, remotely, hybrid; advocacy
- **Data** - data processing, Bernese, design, troubleshooting
- **Governance & Policy** - less exciting, but highly necessary

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Capacity Development - Geodesy Crisis

Geodesy Crisis ....

- Lack of geodesists?
- Lack of resources?
- Lack of funding?
- Lack of support?
- Lack of interest??

All of the above! Plus more!

Succession Planning

- Staff will come and go, retire, leave
- Having succession planning and opening the ’funnel’ for Geodesy
- AI may propagate new Job Roles within Geodesy
  - ‘Geodetic AI Prompt Engineers’
  - **To overcome ’Garbage In, Garbage Out’..**

=> *Geodetic AI Auditors???*

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Capacity Development - Case Studies

Europe has a strong legacy of informal sharing efforts

- CODE
- Nordic Geodetic Commission and Baltic activities - upcoming geoid
- AlpGeoid
- Various Working Groups around various initiatives
- Compliance via various standards

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NOT RELYING ON « BEST EFFORT » ANYMORE

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Objectif du GGCE: création d'un organisme pour la géodésie mondiale dépendant de l'ONU

- **Un parallèle** peut être établi avec l'organisation météorologique mondiale (WMO) qui a démontré les bénéfices d'avoir un congrès et un conseil exécutif.
  - Le budget est d'environ 90 millions d'euros (financement des états membres de l'ONU).
- **Deux possibilités**
  - Étendre les activités du WMO pour inclure la géodésie
  - Création d'une nouvelle organisation dédiée à la géodésie globale (approche favorisée par le GGCE)
    - Dans ce dernier cas, il faut encourager la prise de conscience de l'importance de la géodésie étayée par des preuves scientifiques pour que les Etats membres acceptent de financer cette organisation
    - Exemple: la géodésie contribue aux prévisions météorologiques (produits ZTD)

Examples to copy

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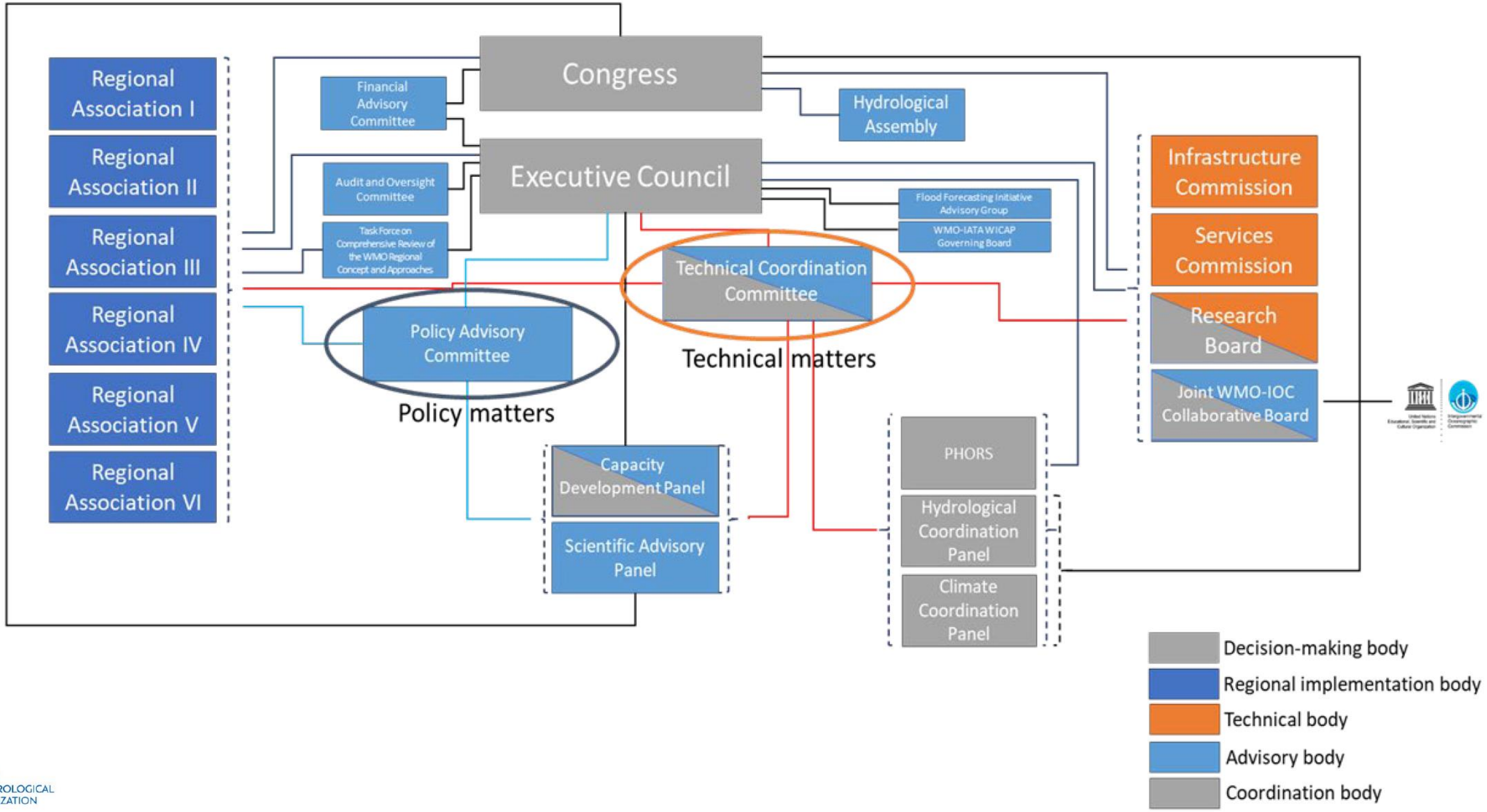
TOGETHER.

WMO Structure



WORLD METEOROLOGICAL ORGANIZATION

UN-GGCE

MEMORANDUM

STRONGER.
TOGETHER.

GGCE Multilateral Memorandum of Understanding (MMOU)

- **Objectifs:**
  - Demonstrate that the global geodesy supply chain (GGSC) is dependent on international cooperation and collaboration, and there is an international 'coalition of the willing' (the Participants of the MMOU) who consider this to be a problem we must work on together.
  - Improve cooperation and collaboration (within existing resources). The MMOU only requires participants to provide a small amount of time from their Representative to share their views, perspectives and updates on activities (without discussing money).
  - Provide a basis for more formal discussions on legally binding bilateral agreements which would include more details about deliverables, activities and resource allocation

- **Le MMOU est devenu opérationnel le 10 mars 2025**

IGN & MMOU

- **En la personne de Nicolas Paparoditis, l’IGN a exprimé son intérêt le 4 mars 2025**
  - Collaborer avec des partenaires internationaux réputés pour améliorer l’intégrité et la durabilité des infrastructures géodésiques dans le monde entier.
  - Une collaboration et une visibilité accrues sur le rôle que joue la géodésie dans nos vies et nos sociétés.
  - Contribuer à l’objectif collectif d’une chaîne d’approvisionnement géodésique résiliente et interconnectée.
    - L'IGN est actuellement en train de constituer un **comité stratégique français des infrastructures d'observation géodésique** pour impliquer toutes les parties prenantes au niveau national.