UNITED NATIONS GLOBAL GEODETIC CENTRE OF EXCELLENCE

MODERNISING GEOSPATIAL REFERENCE SYSTEM CAPACITY DEVELOPMENT WORKSHOP

Introducing regional collaboration in geodesy

Nicholas Brown
Head of Office, UN-GGCE

WHO

Day 1, Session 3 [1_3_1]

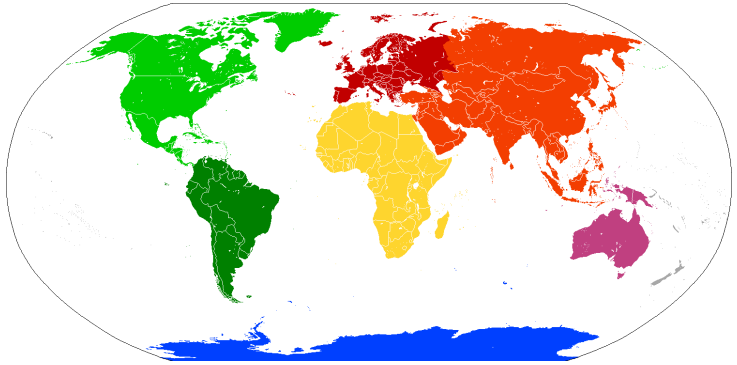
Acknowledgements: Abdullah AlQahtani (KSA); Zuheir Altamimi (FRA); Fernand Bale (CIV); Detlef Angerman (TUM); Johannes Bouman (GER); Dana J Caccamise II (USA); Sergio Cimbaro (ARG); Gustavo Caubarrere (URY); Andrick Lal (SPC); Anna Riddell (AUS); Daniel Roman (USA); Jeffrey Verbeurgt (BEL).

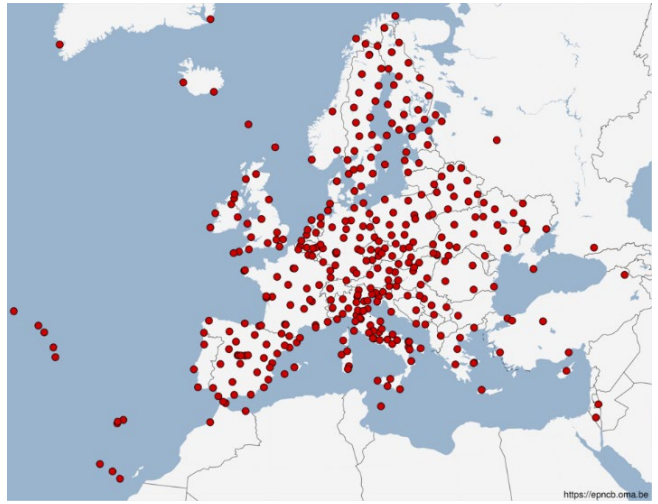
Summary

- Regional reference frames are densified versions of the International Terrestrial Reference Frame (ITRF).
  - The realization of ITRF restricts the number of GNSS sites for computational reasons
  - The purpose of ITRF is to determine an accurate global model (not monitor geophysical processes)
- Regional reference frames provide a strong basis for national geodetic datum development however they are not essential.
- Different regions perform create regional reference frames differently.

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





STRONGER.
TOGETHER.

Benefits of a regional reference frame

- Learning and working together to:
  - accurately analyze GNSS data
  - determine geodetic parameters
  - use GNSS data for scientific and societal applications
- Need cooperation: data, analysis & combination centers
- Need data sharing between countries
- Leads to densification of ground stations
- Improved access to the ITRF using IGS products

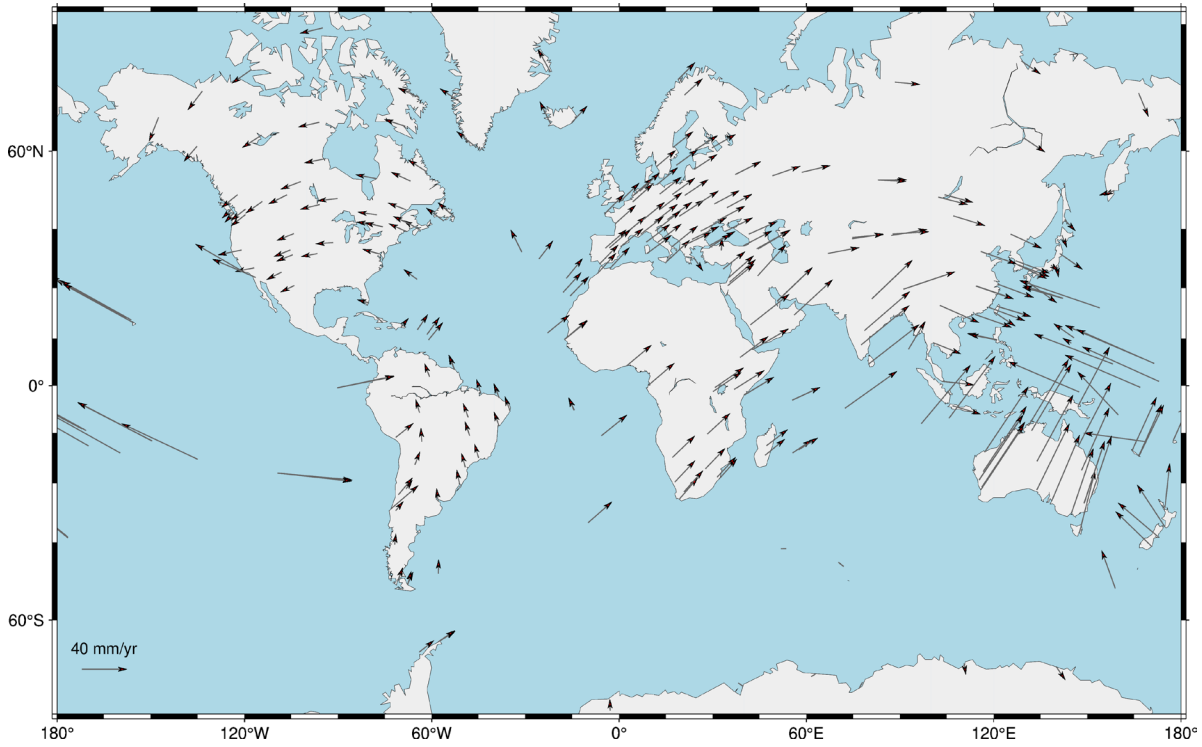
Ways to create a regional reference frame

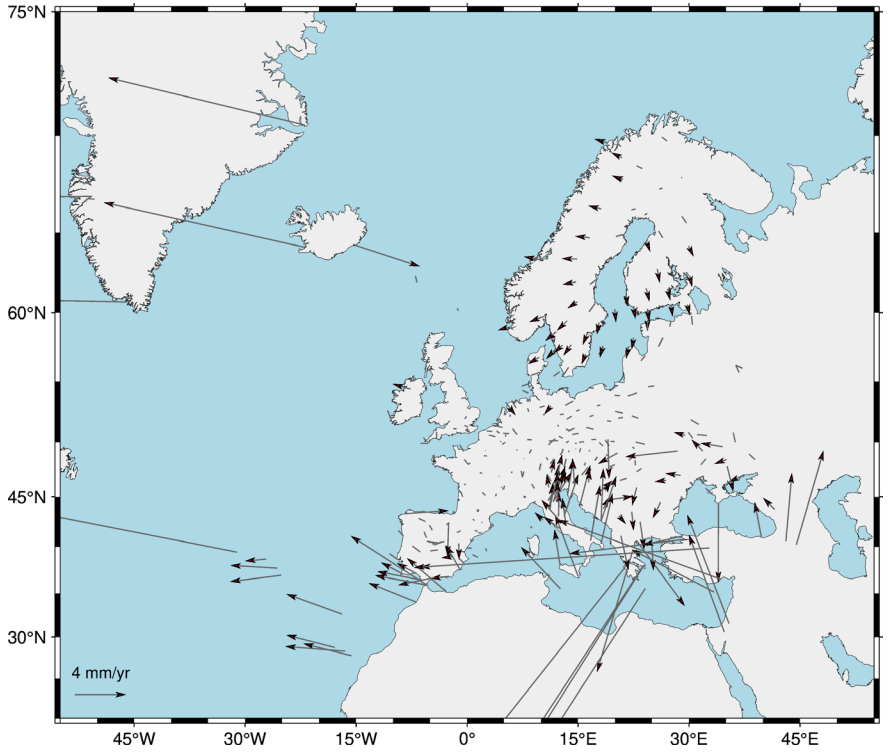
European Terrestrial Reference System 1989 (ETRS89)

- Regional realization of the ITRF fixed to the Eurasian plate at epoch 1989.0.
- ETRS89 is static
- Since the Eurasian plate moves at an approximate rate of **2.5 cm per year relative to the ITRF**, the difference between the ITRF and ETRS89 increases with time. To handle this, a **time-dependent transformation** is applied:
  - GNSS-derived coordinates are calculated in the ITRF for the observation epoch (e.g., 2025.0). These coordinates are then transformed back to the ETRS (as referenced to 1989.0 (or an epoch of their choosing)) using plate motion models and transformations (e.g. NNR-NUVEL-1A or more recent versions (e.g., ITRF2014 Plate Motion Model or ITRF2020 Plate Motion Model).
- Coordinate velocities are “minimized" instead of “eliminated“. While continental drift is largely mitigated, there are residual effects that cannot be entirely removed:
  - Local Tectonic Deformation: Regions within Europe that experience seismic activity or crustal deformation (e.g., near plate boundaries or fault zones) may still see small positional changes over time.
  - Plate Flexing: Even within the "stable" part of the Eurasian plate, minor deformations can occur, causing slight deviations in position over long periods.
- Updates to ETRS89 (e.g., ETRF2000, ETRF2014) are released periodically to reflect advancements in geodesy but maintain the static plate-fixed assumption.
- Uses fixed transformations to align GNSS-derived coordinates (in ITRF) with the static Eurasian plate framework.

Ways to create a regional reference frame

European Terrestrial Reference System 1989 (ETRS89) – “minimizing the residuals”





Ways to create a regional reference frame

Asia-Pacific Reference Frame (APREF)

- Regional realization of the ITRF not a single tectonic plate but is instead a direct realization of the ITRF for the Asia-Pacific region.
- APREF is a time dependent reference frame
- APREF Central Bureau provides updated coordinates weekly to reflect tectonic plate motions, seismic shifts, and other geodynamic processes.
- Some national geodetic datums use the time dependent APREF as constraint for national static datums (e.g. Australia and New Zealand)
- Australia uses a plate motion model based on APREF data to propagate coordinates between the national static datum (fixed to 2020) and ITRF
- New Zealand uses a deformation model based on APREF data (and local data pre and post earthquakes) to propagate coordinates between the national static datum (2000) and ITRF.
- The regional time dependent reference frame supports applications in the Asia-Pacific region, where plate motion and seismic activity are significant (e.g. earthquake monitoring, tsunami warning systems, and high-precision navigation)
- While both **ETRS89** and **APREF** serve as regional geodetic reference frameworks, their operation and design reflect their respective tectonic environments. The **ETRS** is static, tied to the Eurasian plate, and suited for Europe's relatively stable context. The **APREF**, on the other hand, operates dynamically in direct alignment with the ITRF, reflecting the tectonic activity and complexity of the Asia-Pacific region.

Ways to create a regional reference frame

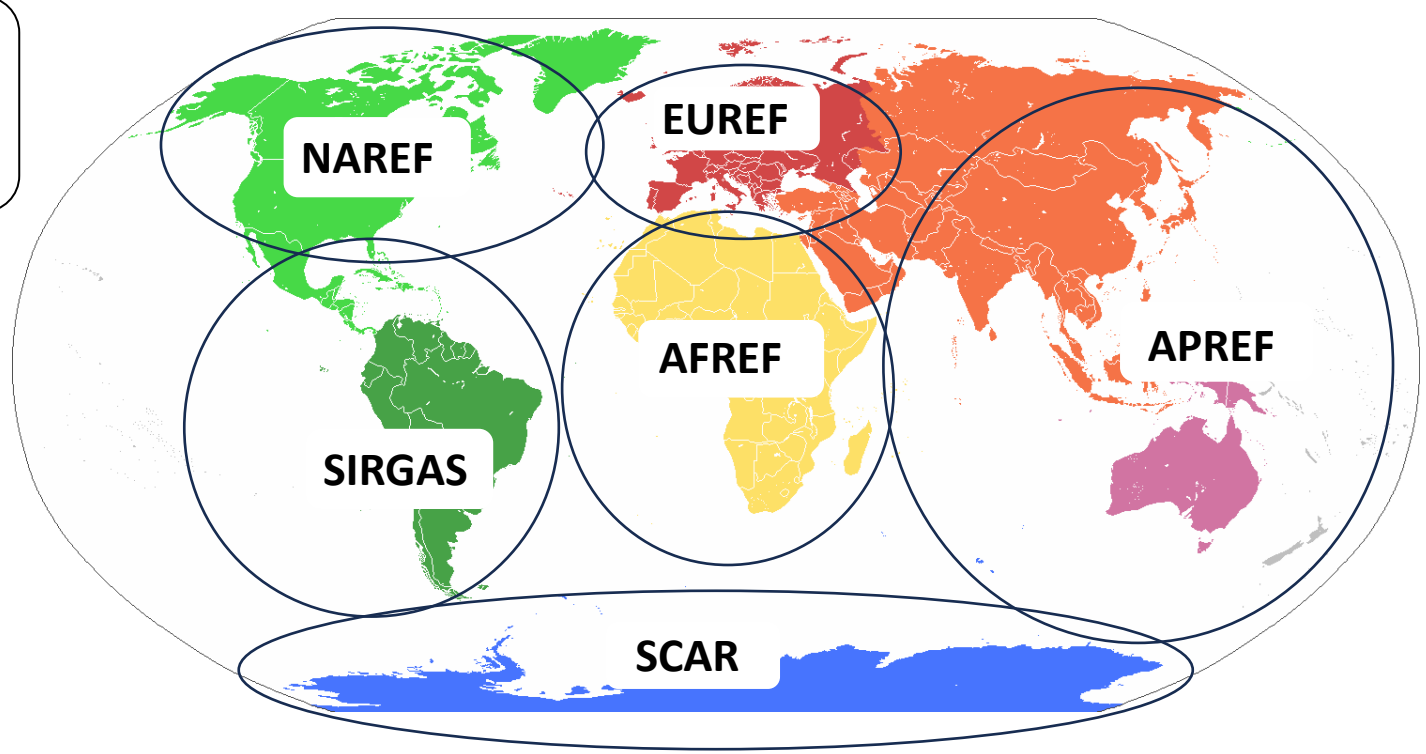
	Europe	**Asia-Pacific**	**Americas**
Static / Time Dependent	Static	Time Dependent	Time Dependent
Epoch	1989	Middle of each week	Middle of each week

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

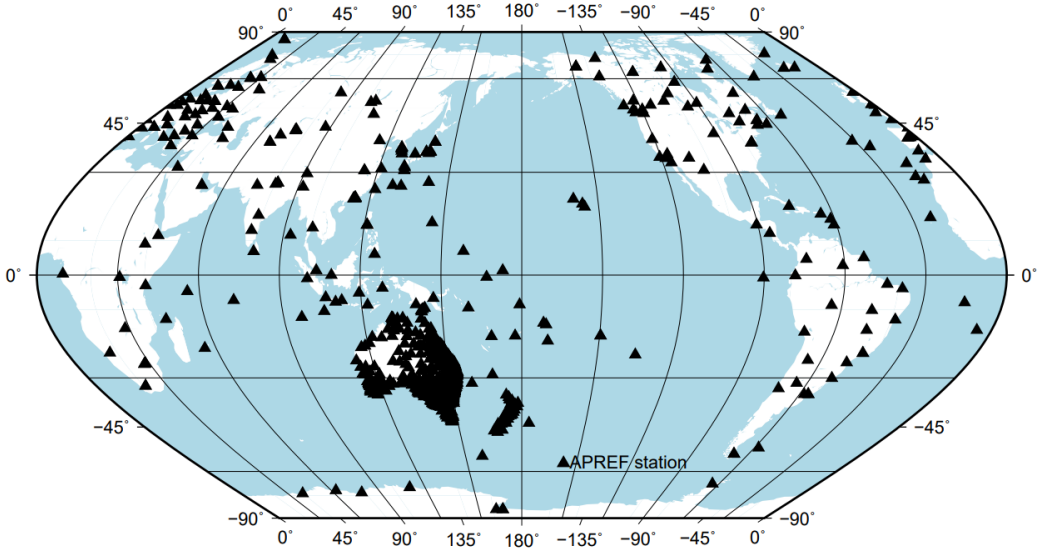
AFREF
1.3d
Africa

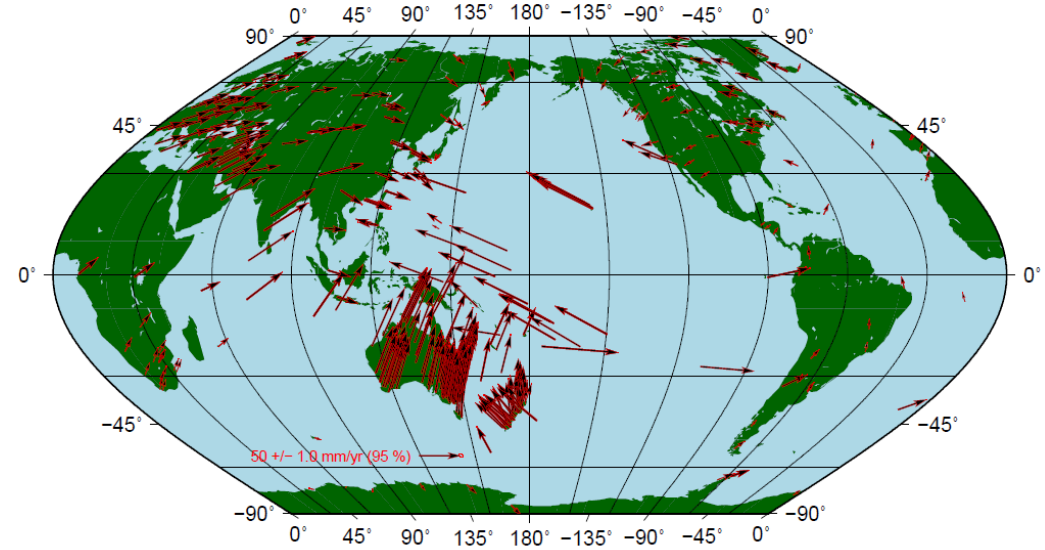
APREF
1.3e
Asia Pacific

SCAR
1.3f
Antarctic

APREF (Asia Pacific Reference Frame)

- Densification in Asia-Pacific region
- Total 1053 CORS (2023)
- Including 332 IGS20 CORS
- Three regional GNSS analysis centres
- Geoscience Australia develops a combined solution from the analysis centres
- Central Bureau in Geoscience Australia





EUREF

- About 450 stations
- 16 Analysis centers
- ETRS 89 – European Terrestrial Reference System
- Coincides with ITRF at epoch 1989.0
- Tied to continental plate
- Basis for precise GNSS in Europe
- Different national realizations based on ITRS89
- Example Realization Germany: ITRS89/DREF91

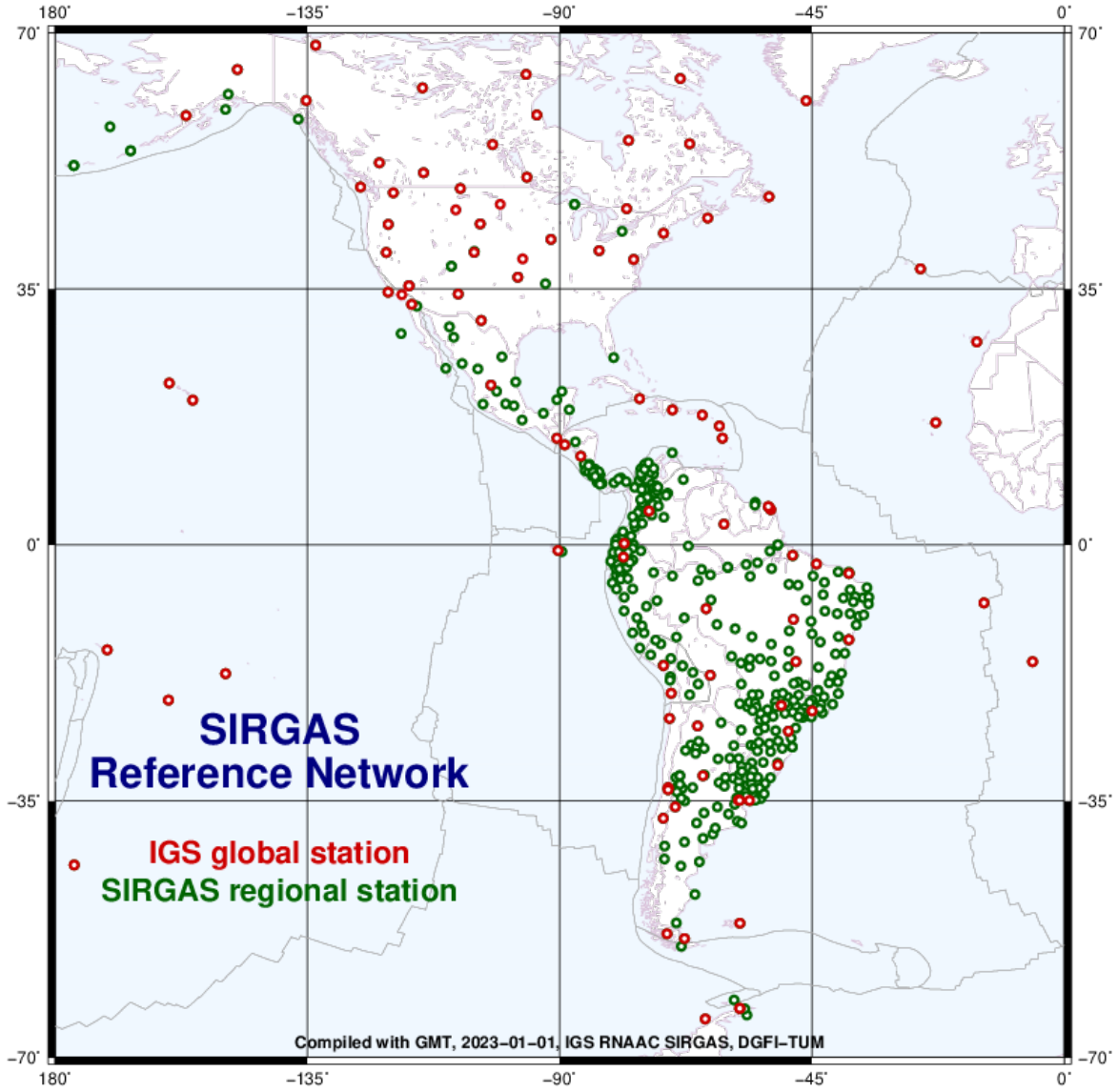
SIRGAS

- **SIRGAS: Sistema de Referencia Geodésico para las Américas**
  - In English: Geodetic Reference System for the Americas
  - **SIRGAS has roots in** both the International Association of Geodesy **(IAG) and** the Pan American Institute of Geography and History **(PAIGH)**
    - SIRGAS is IAG 1.3b but is separately an NGO for the Americas

  - **Three WG's inside SIRGAS**
    - **WG1** – Reference System: combines IAG 1.3b, 1.3c (SIRGAS and NAREF)
    - **WG2** - SIRGAS at national level: National implementation of SIRGAS
    - **WG3** – Vertical Datum: combines IAG 2.4b and 2.4c (GG in SA and GG NCA)

SIRGAS

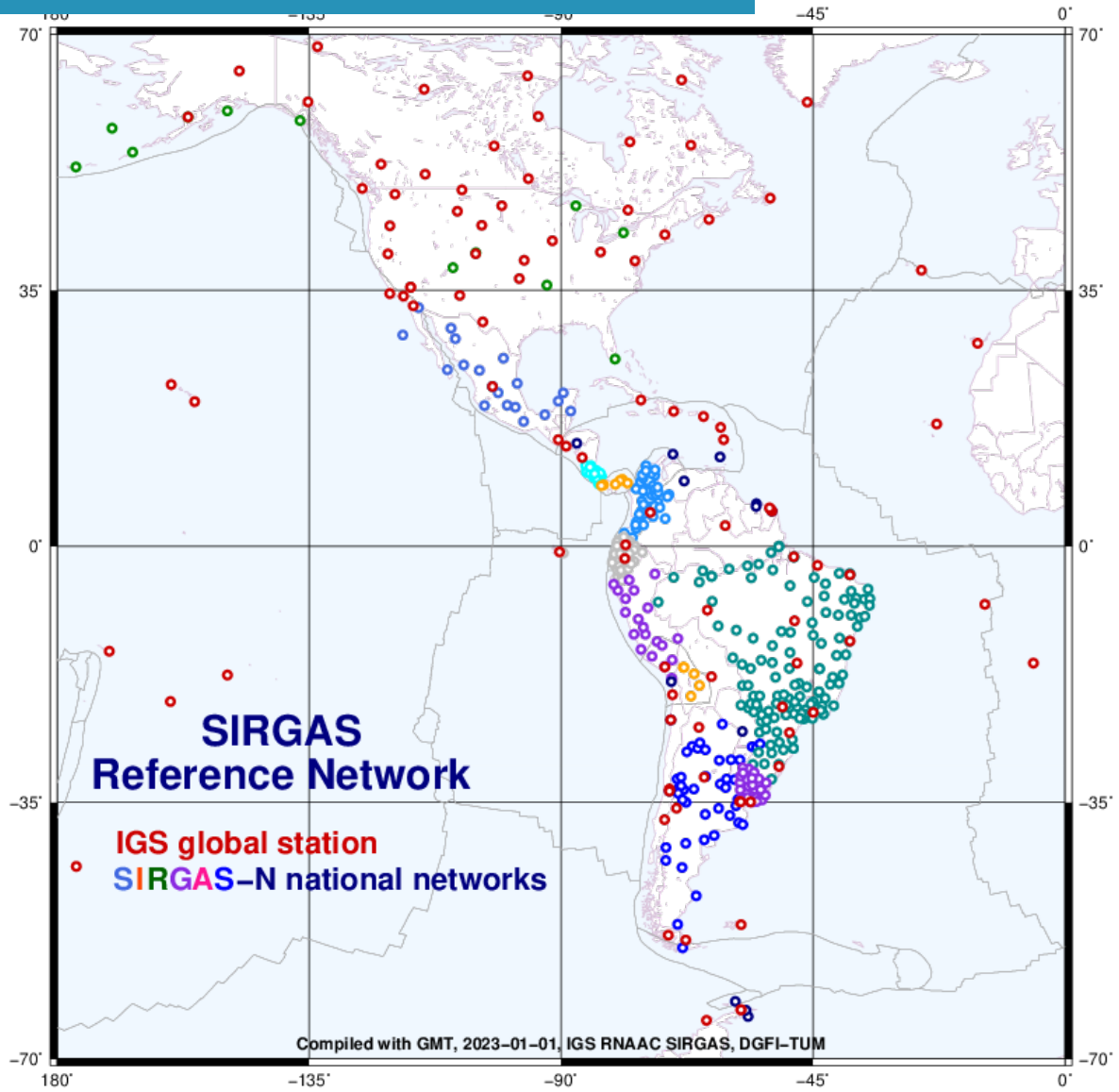
- About 500 stations
- Regional Analysis Center of Associates of the IGS Network for SIRGAS (IGS, RNAAC, & SIRGAS)
- 11 SIRGAS Processing Centres (Local) in the Americas Nations
- Two SIRGAS Combination Centres
- VLBI Analysis Center of IVS
- SLR processing Center in progress
- SIRGAS-N - National reference network.
- Improves the densification of the core network
- Provides national and local access to the reference frame
- Both, SIRGAS-C and SIRGAS-N satisfy the same characteristics and quality
- Each station is processed by three analysis centres.



SIRGAS

Almost all countries in the Americas are aligned with ITRF.

They are working to incorporate all countries, particularly those in the Caribbean.



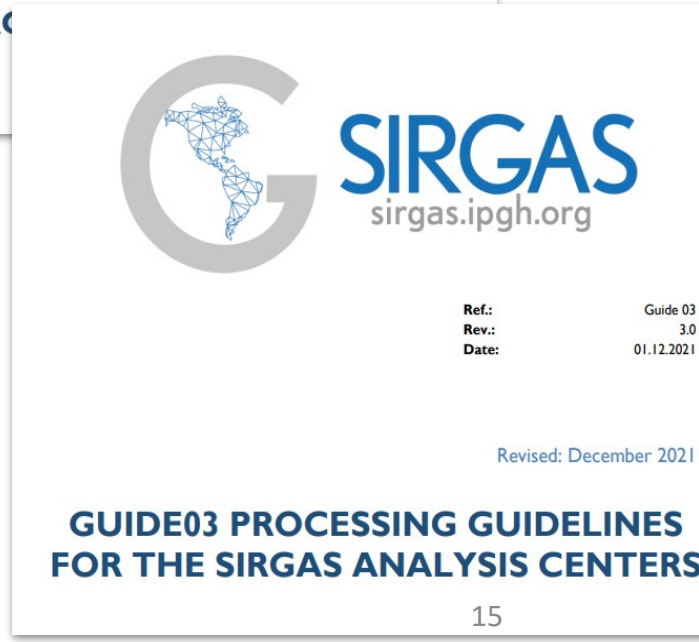
SIRGAS

Technical guidelines

- Guidelines for the Coordination of the SIRGAS Continuously Operating Network (SIRGAS-CON)
- Guidelines for the installation, operation and registration of SIRGAS-CON stations
- Guidelines for SIRGAS Analysis Centers
- Guidelines for IHRF station selection
- Guidelines for performing gravimetric measurements around IHRF stations

Recommendations

- IGS site guidelines
- Monumentation of permanent GNSS stations ? UNAVCO
- Physical Site Specifications: Geodetic Site Monumentation (W.L. Combrinck and M. Schmidt)
- NOAA/NGS Guidelines for establishing and operating CORS

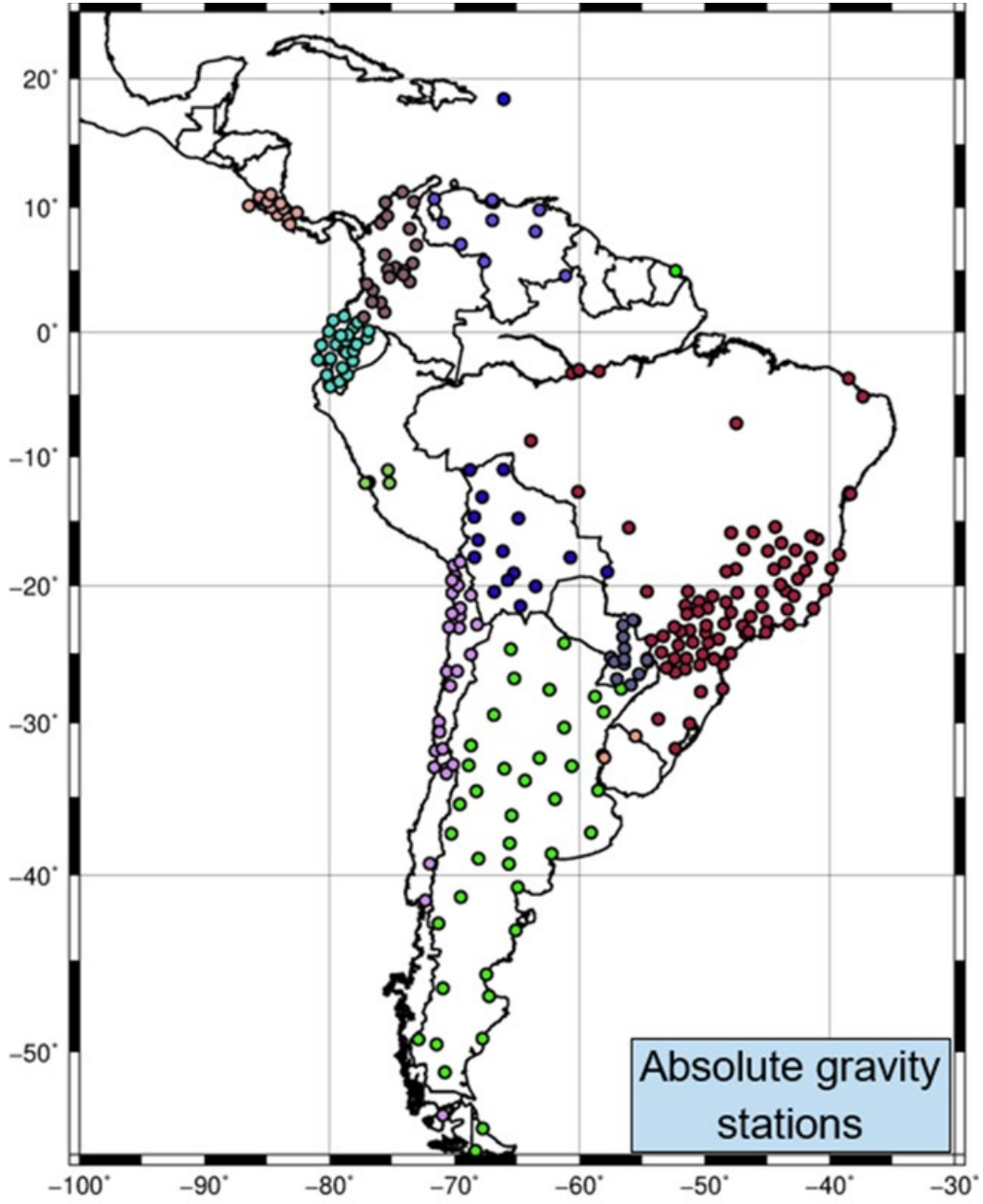


SIRGAS

IAG 2.4b

SIRGAS works together with universities and geographic institutes to determine absolute gravity stations in the region.

SIRGAS encourages countries to keep data open and share gravity information in the AGrav (Absolute Gravity Database) repository of the International Gravity Field Service (IGFS) (agrav.bkg.bund.de).



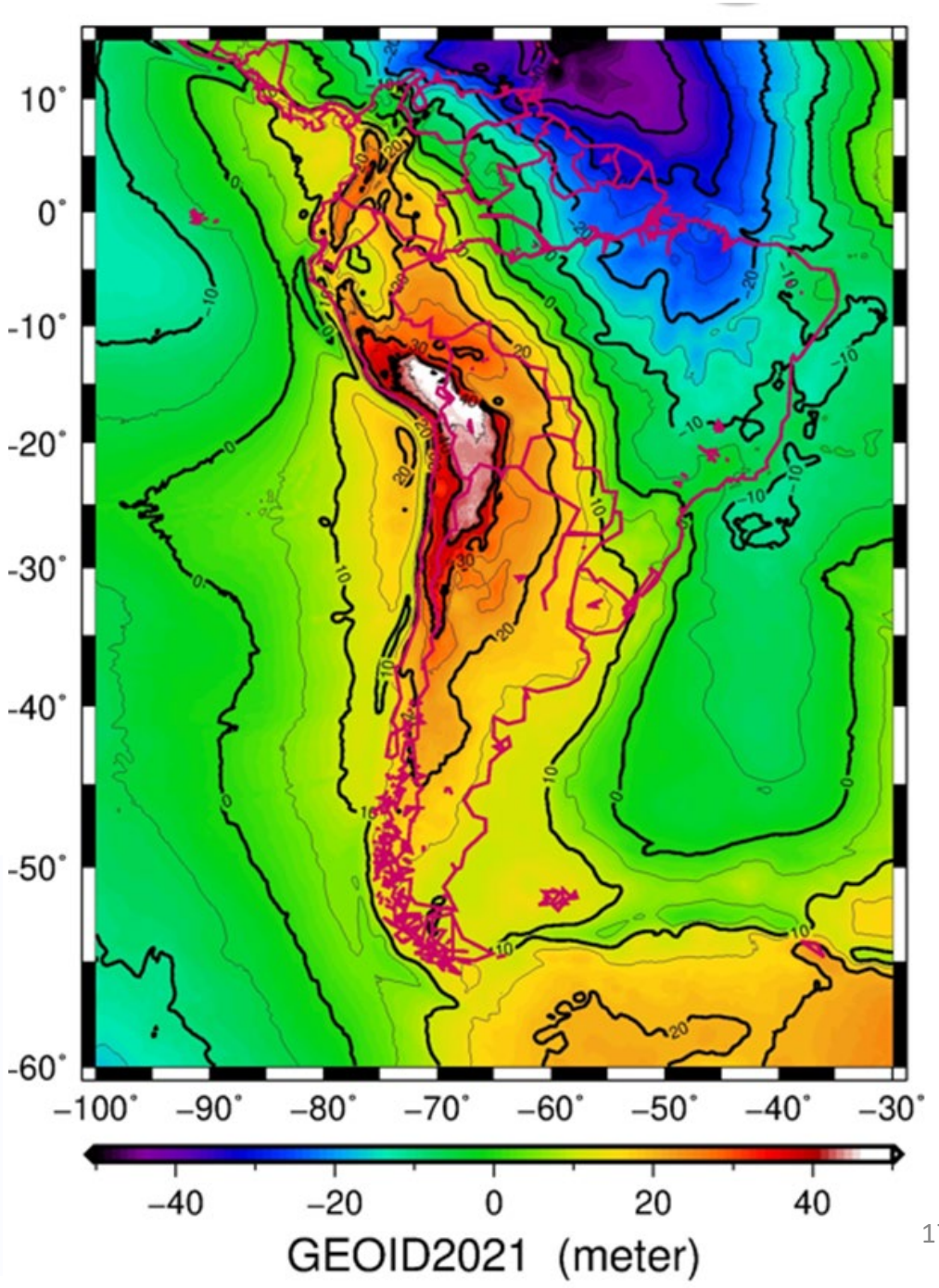
SIRGAS WG 3 - cont

IAG 2.4b

SIRGAS makes geoid models available for the South American community. The models are available for download on the International Geoid Service (ISG) page of the International Geodesy Association.

Regional Models by list for SOUTH AMERICA

Zone	Description	Year	Status
South America	Gravimetric Geoid	2010	PUBLIC
South America (GEOID2015)	Gravimetric Geoid	2015	PUBLIC
South America (GEOID2021/QGEOID2021)	Gravimetric Geoid and Quasi-Geoid	2021	PUBLIC



ARABREF

2014, Aug

- **UN-GGIM: AS established by the UN-GGIM in the fourth session in New York in August 2014.**
- **Number of countries:** 22
- **Arab States Members:**

  - **Algeria**
  - **Bahrain**
  - **Comoros**
  - **Djibouti**
  - **Egypt**
  - **Iraq**
  - **Jordan**
  - **Kuwait**
  - **Lebanon**
  - **Libya**
  - **Mauritania**
  - **Morocco**
  - **Oman**
  - **Palestine**
  - **Qatar**
  - **Saudi Arabia**
  - **Somalia**
  - **Sudan**
  - **Syria**
  - **Tunisia**
  - **United Arab Emirates**
  - **Yemen**

ARABREF

UN-GGIM-AS: Arab States: Geodetic Reference Frame Working Group (GRF-WG)

Geodetic Reference Frame Working Group: New Structure

- **Function:**

  Provide a forum for dialogue and coordination between members of the UN-GGIM: Arab States, United Nations system, and other relevant stakeholders with a view to –

  - Align with efforts to implement General Assembly Resolution 69/266 – 'A global geodetic reference frame for sustainable development.
  - Exchange information and experiences to improve national awareness and investment in geodesy.
  - Collaborate with other efforts of regional committees on UN-GGIM on issues of common interest in geodesy and recognize important and relevant partners and stakeholders in successfully planning and implementing an effective geodetic network.
  - Explore sharing geodetic data to contribute to the densification of Arab States regional geodetic network as well as the global geodetic reference frame and identify and address issues that inhibit such collaboration and sharing.
  - Improve standards as appropriate and coordinate standards requirements.
  - Plan, organize and conduct workshops and training activities on geodesy and its importance as part of capacity development.
  - Develop and/or use existing communication information to educate others on the importance of geodesy and the geodetic framework for national, regional, and global benefits.

- **Approved to transfer the ARABREF project from UN-GGIM:AS and register it within the Regional Reference Frame under the International Association of Geodesy (IAG)**

- **Approved the representatives MS of UN-GGIM-AS on the SCoG to be :**

  - **Algeria**
  - **Lebanon**
  - **Oman**
  - **Qatar**
  - **Saudi Arabia**
  - **Iraq**

2014
(Foundation of UN-GGIM:AS)

2015
(Foundation of GRF-WG)

2016, Feb
Initiation of ARABREF concept

2016, Nov
Preliminary ARABREF Road map

2017
ARABREF Benefits and Definition

2018
Data & Analysis Centers Proposals

2019
Establish Data&Analysis Centers

2020
Alignment with SCoG

2021
Workshops and Workplan

2023
strategic objectives Extension

2024, Feb

ARABREF

UN-GGIM-AS: Arab States: Geodetic Reference Frame Working Group (GRF-WG)

ARABREF: Challenges

- GNSS CORS data is shared only from two GRF-WG members.
- Lack of Geodetic expertise in GRF-WG