



Review of GNSS Infrastructure, Gaps & Optimum Location of New GNSS Site for the Africa Reference Frame (AFREF)

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Objectives of AFREF

Formally established with Windhoek Declaration in 2002:

- To determine a continental reference frame for Africa consistent and homogeneous with the global reference frame of the ITRF as a basis for national 3-d reference networks.
- To realize a unified vertical datum and to support efforts to establish a precise African geoid.
- To establish a network of continuously operating, permanent GNSS base stations at a spacing such that the users will be within 1000km of a base station and that data is freely available to all nations.

Objectives of AFREF

- To determine the relationship between the existing national reference frames and the ITRF to preserve legacy information based on existing frames.
- To provide a sustainable development environment for technology transfer so that these activities will enhance the national networks and other applications.
- Assist in establishing in-country expertise for implementation , operation, processing and analysis of modern geodetic techniques, primarily GNSS.

Reference Frames: what for?



❑ Surveyors

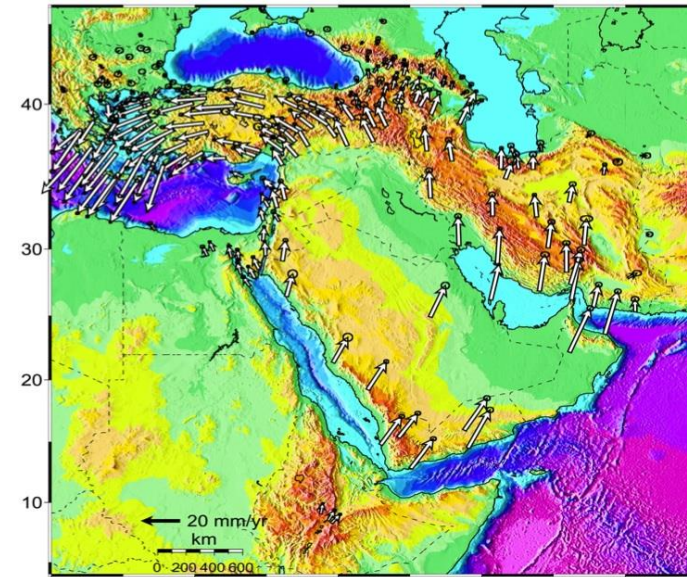
- Mapping (cadastral, GIS, remote sensing etc)
- Engineering (route design etc)

❑ Geodesists

- Plate motion (deformation study)
- Transformation between systems

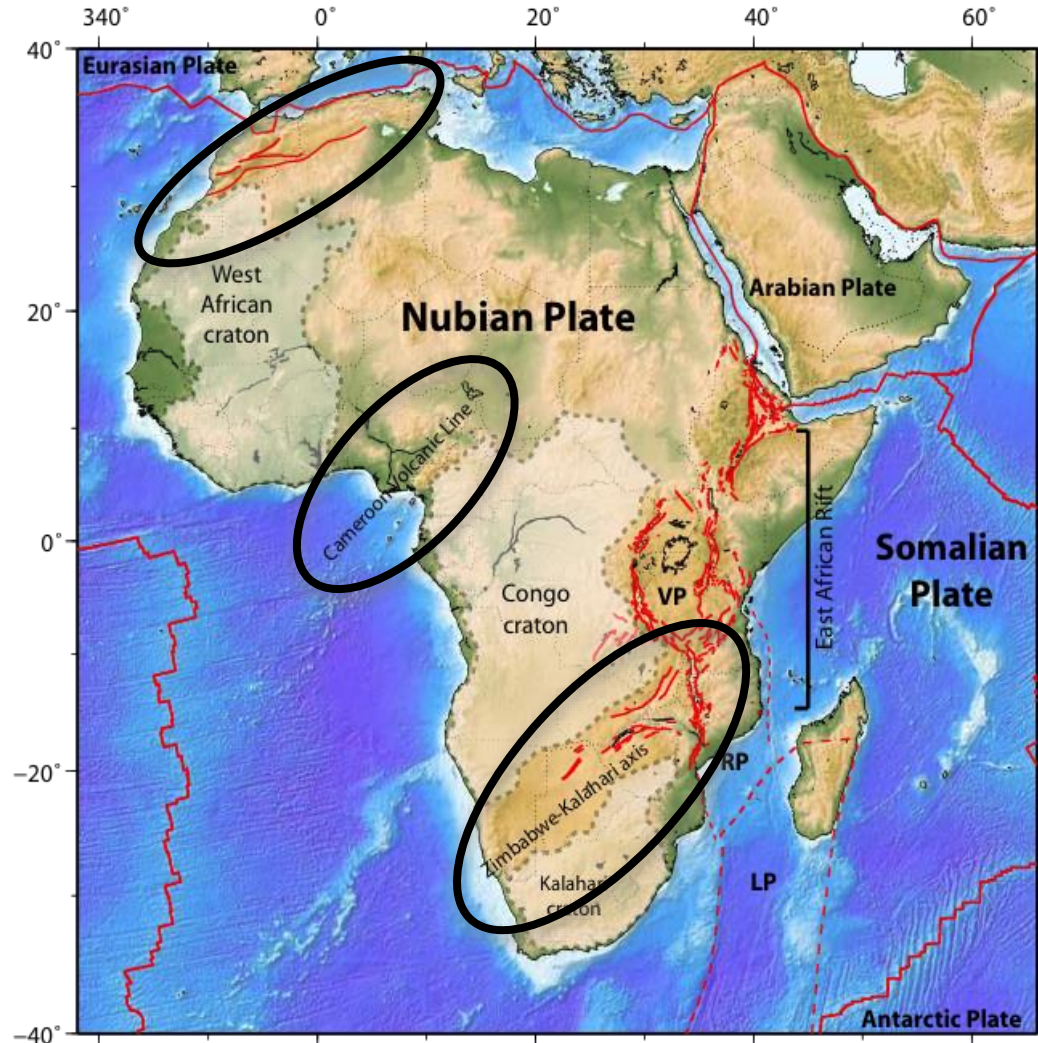
❑ Geophysicists

- Tectonic interpretations
- Hazard studies



Reillinger-2006 Velocity wrt Eurasia

What to Consider for AFREF



RF - realized on rigid part of the continent (e.g. *EUREF*, *NAREF*)

- To be consistent through time with little or no distortion

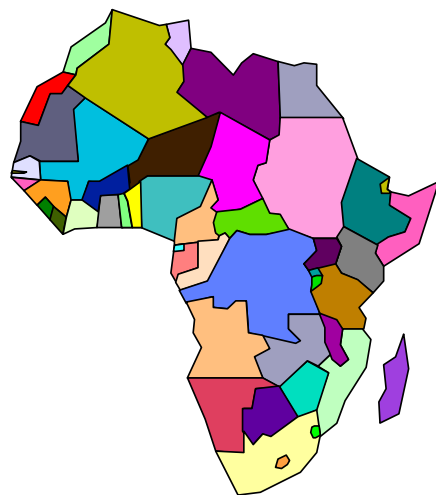
AFREF- to be realized on Nubia

- How tectonically stable is the Nubian plate interior?

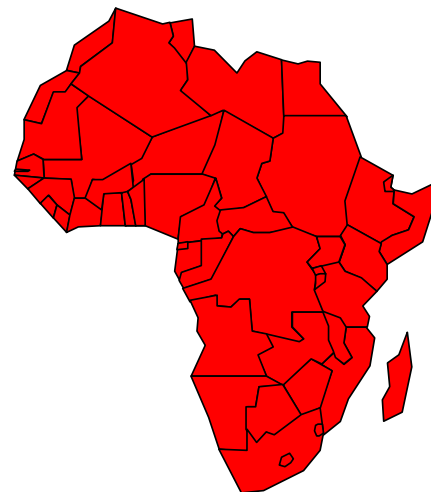
AFREF definition requires to understand

- Present-day kinematics of Nubia (& level - internal deformation)
- Kinematic of the EAR

AFREF



**GNSS
+
ITRF**



**AFREF – Common
Geodetic RF for all African
countries**

Or

**Appropriate Frame to
describe Position + Velocity
of sites spanning Africa**

Application

- ✧ Uniform mapping/engineering projects
- ✧ Resolve international boundary disputes
- ✧ Facilitate regional geophysical interpretation
- ✧ Add GPS sites for meteorological studies
- ✧ Orbital determination + ITRF = precise orbit + contribution to ITRF

The AFREF Operational Data Centre (ODC)



AFREF Reference Station Web Server <http://afrefdata.org/>

- [Home](#)
- [Map](#)
- [30sec Rinex Files](#)
- [Logout](#)

Welcome to the AFREF Webserver for GNSS-Reference stations

The African Geodetic Reference Frame (AFREF) is a project designed to unify the very many geodetic reference frames of Africa using data from a network of permanent Global Navigation Satellite Systems (GNSS) stations as the primary data source for the realization of such a uniform reference frame. Numerous National Mapping Agencies and Universities in Africa, International agencies and organisations have installed suitable geodetic grade GNSS receivers at many locations throughout Africa. For more information on AFREF see <http://geoinfo.uneca.org/afref/Intro.htm>

Data from these stations is being archived on a number of data bases. The AFREF Operational Data Centre (ODC) collects data on a daily basis from as many of these datasets as are freely available. Although most known stations have been shown on the map, data for the interactive stations only is available. This then is the data to be found on this website.

The AFREF ODC has been set up as part of the activities of the AFREF Steering Committee and in compliance with the guidelines of the International GNSS Service (IGS) (<http://igs.cb.jpl.nasa.gov/>)

User name and password is not required. Use guest logon

Please note that all GNSS data is supplied in the standard RINEX format at 30 second epoch.

Currently only 30 second 24 hour daily files are being archived. The file naming convention conforms to the IGS standard

SSSSDDD0.YYd.Z

Where:

YY = year

DDD = day of year

SSSS = site name

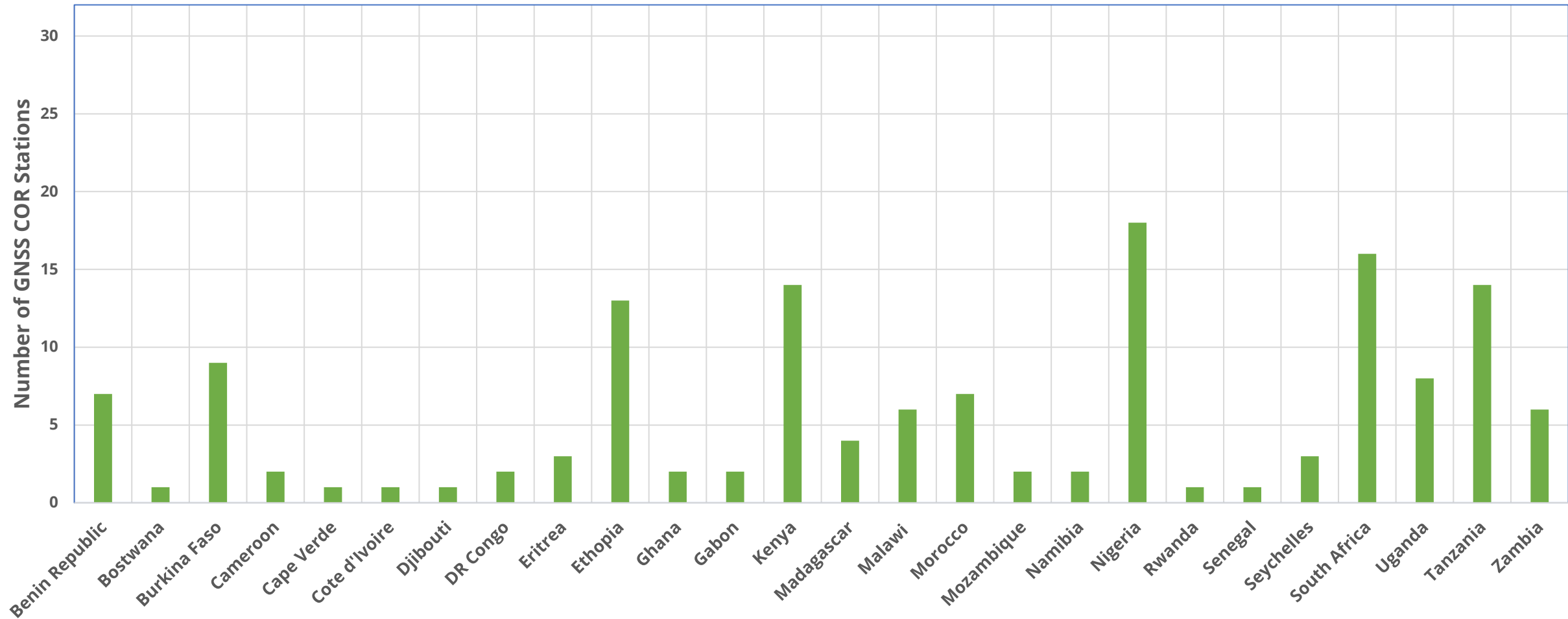
0 = 24 hour file

d = compress observation file



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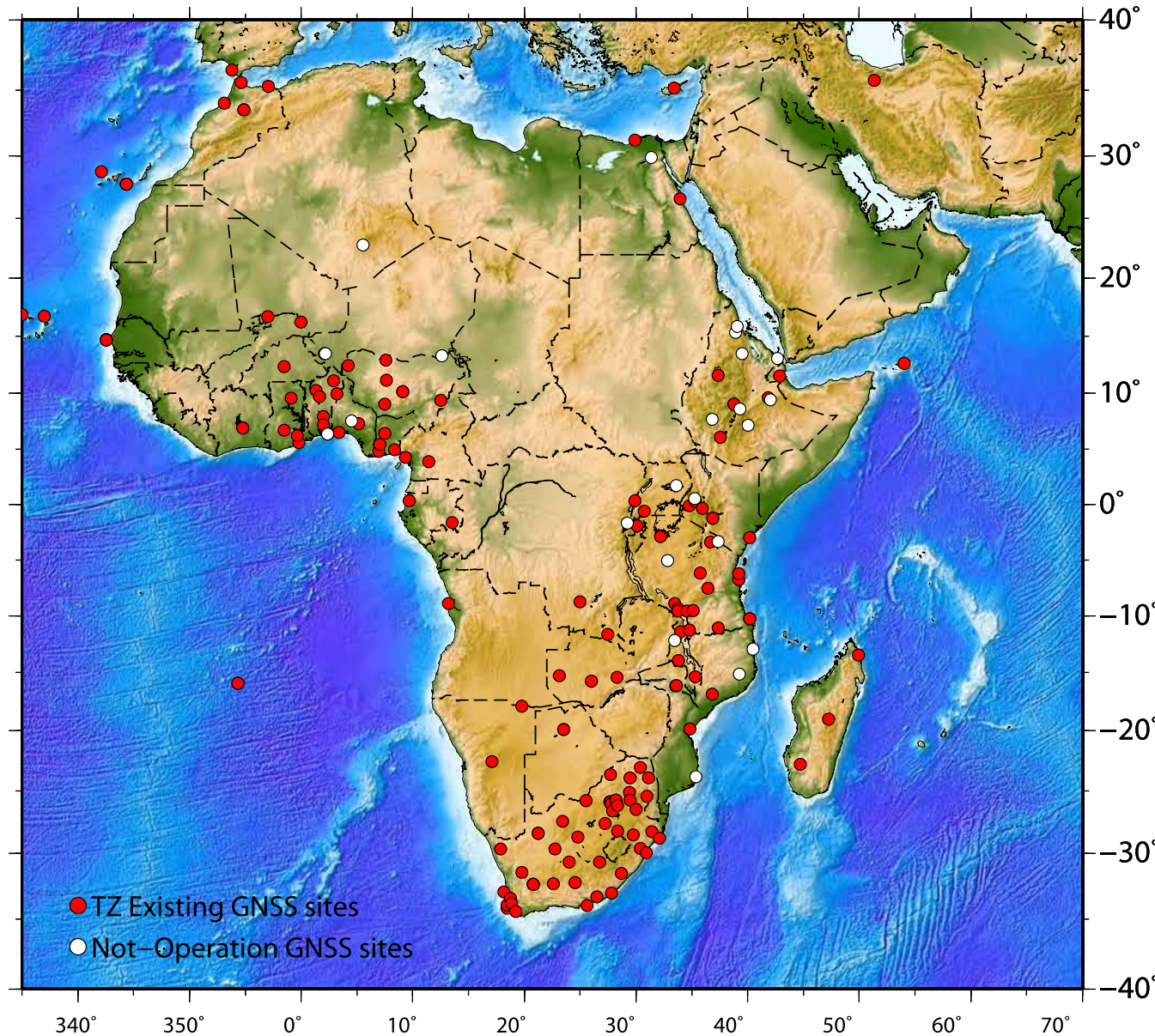
GNSS CORS Infrastructure Countrywise



List of African Countries (26)

July, 2022

GNSS Infrastructure in Africa



Efforts

- Individual countries initiatives with dense cGPS *e.g. South Africa, Nigeria, Benin, Kenya, Ethiopia etc.*

- International Initiatives – *e.g.*

- AA project,

- AMMA,

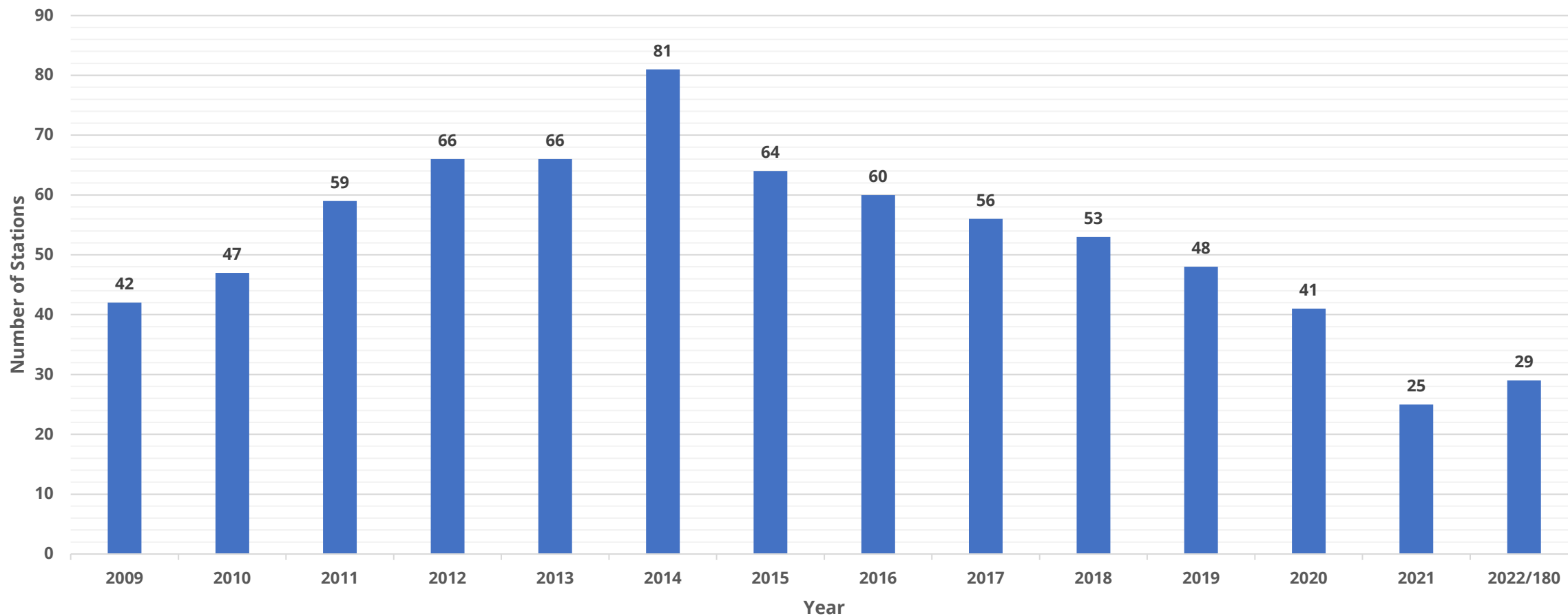
- SEGMENT

- IGS

- etc

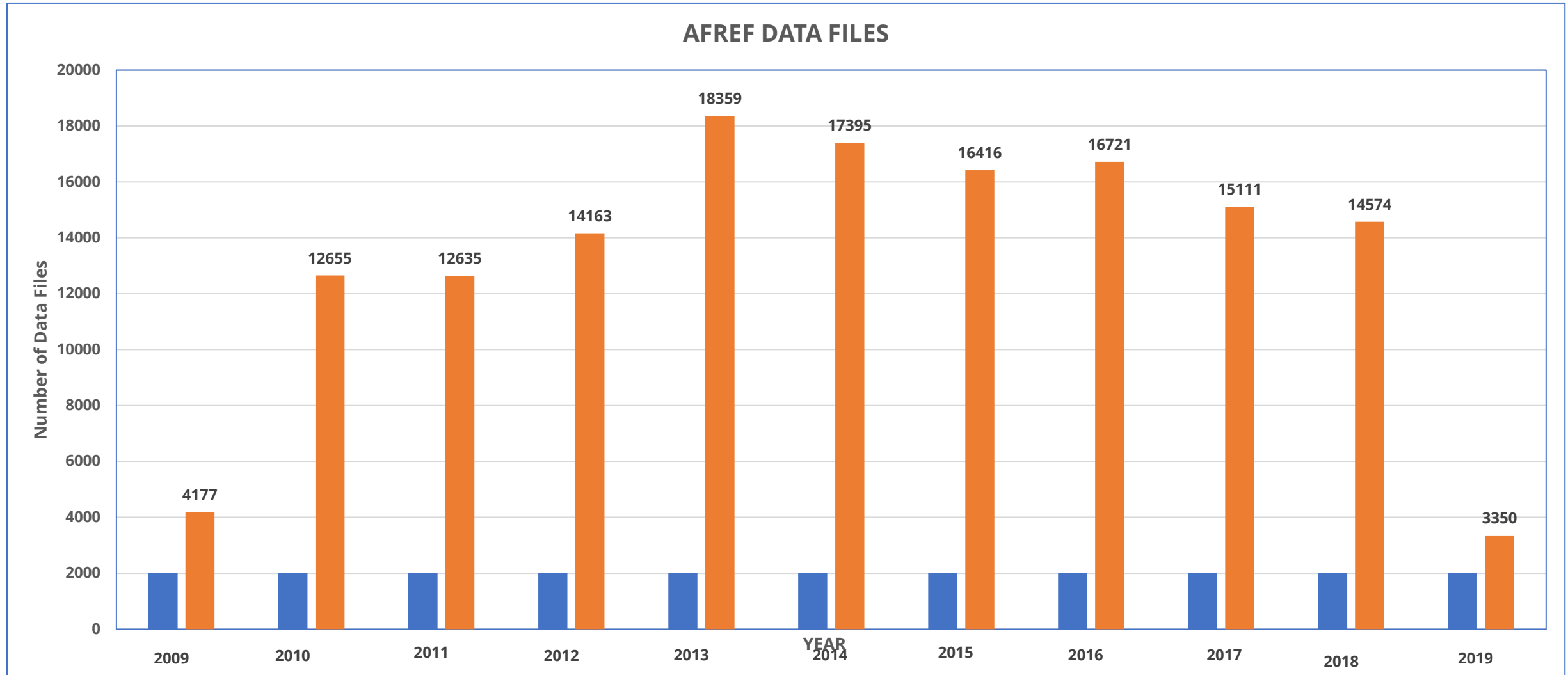
The AFREF Operational Data Centre (ODC)

AFREF STATION CONTRIBUTION



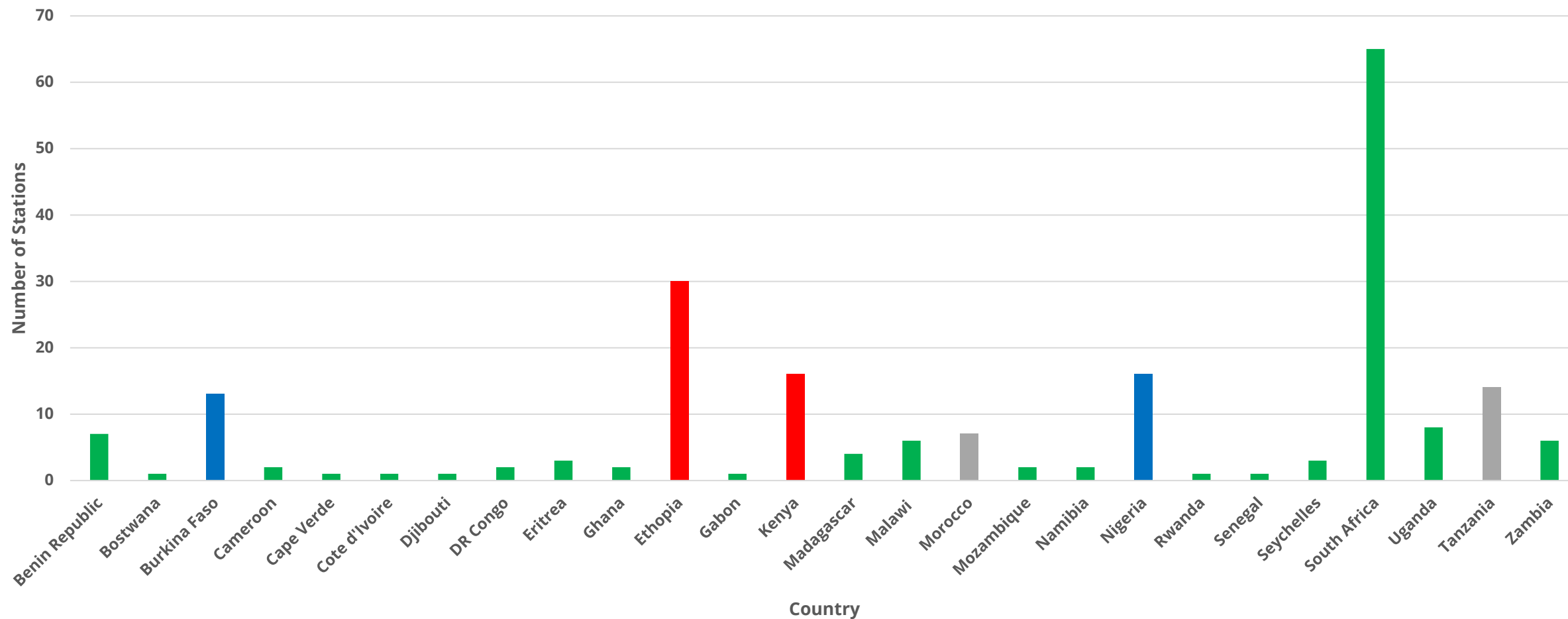
<http://afrefdata.org/> July, 2022

The AFREF Operational Data Centre (ODC)



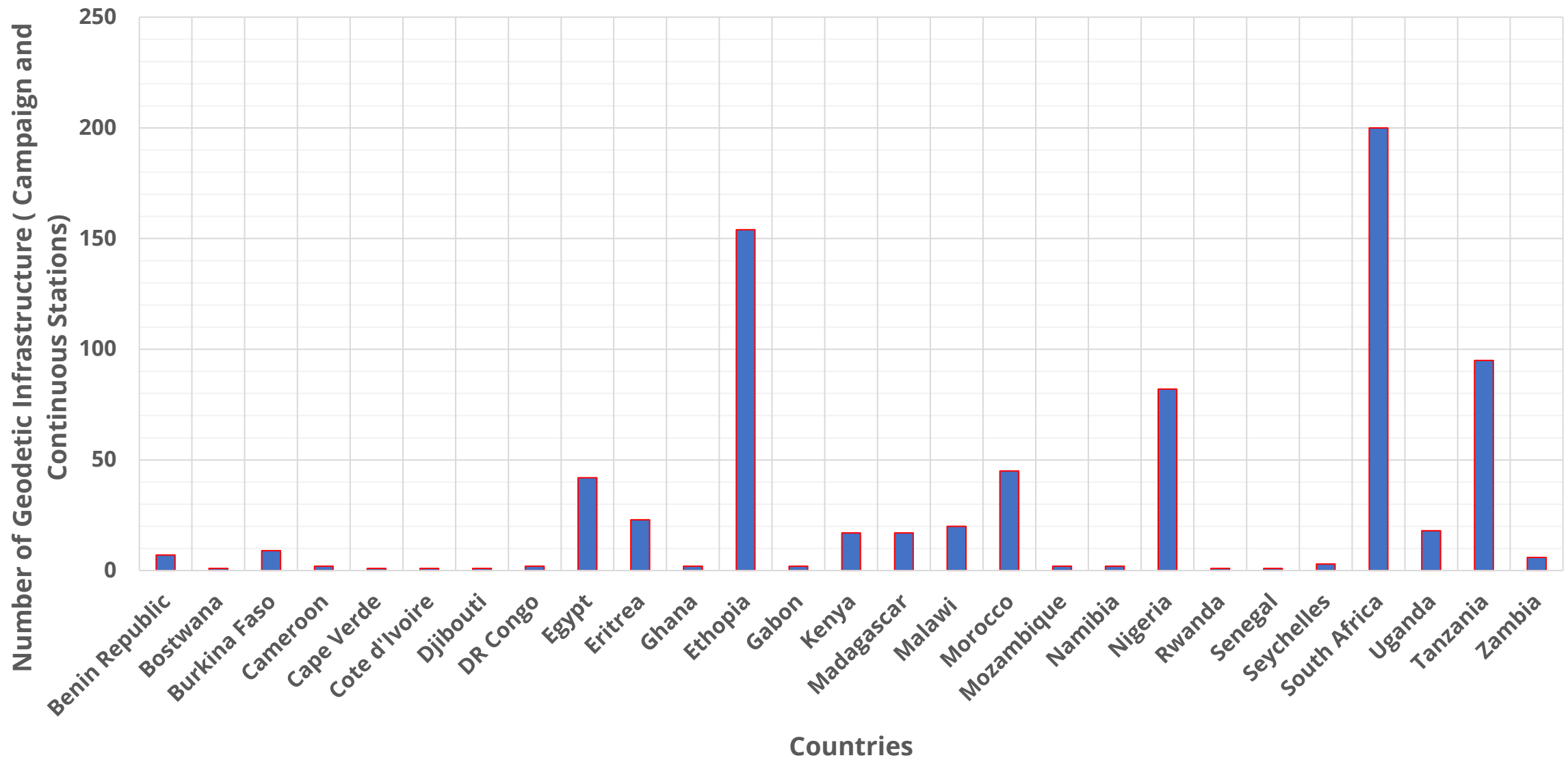
<http://afrefdata.org/> July, 2022

Countries with Online GNSS Data

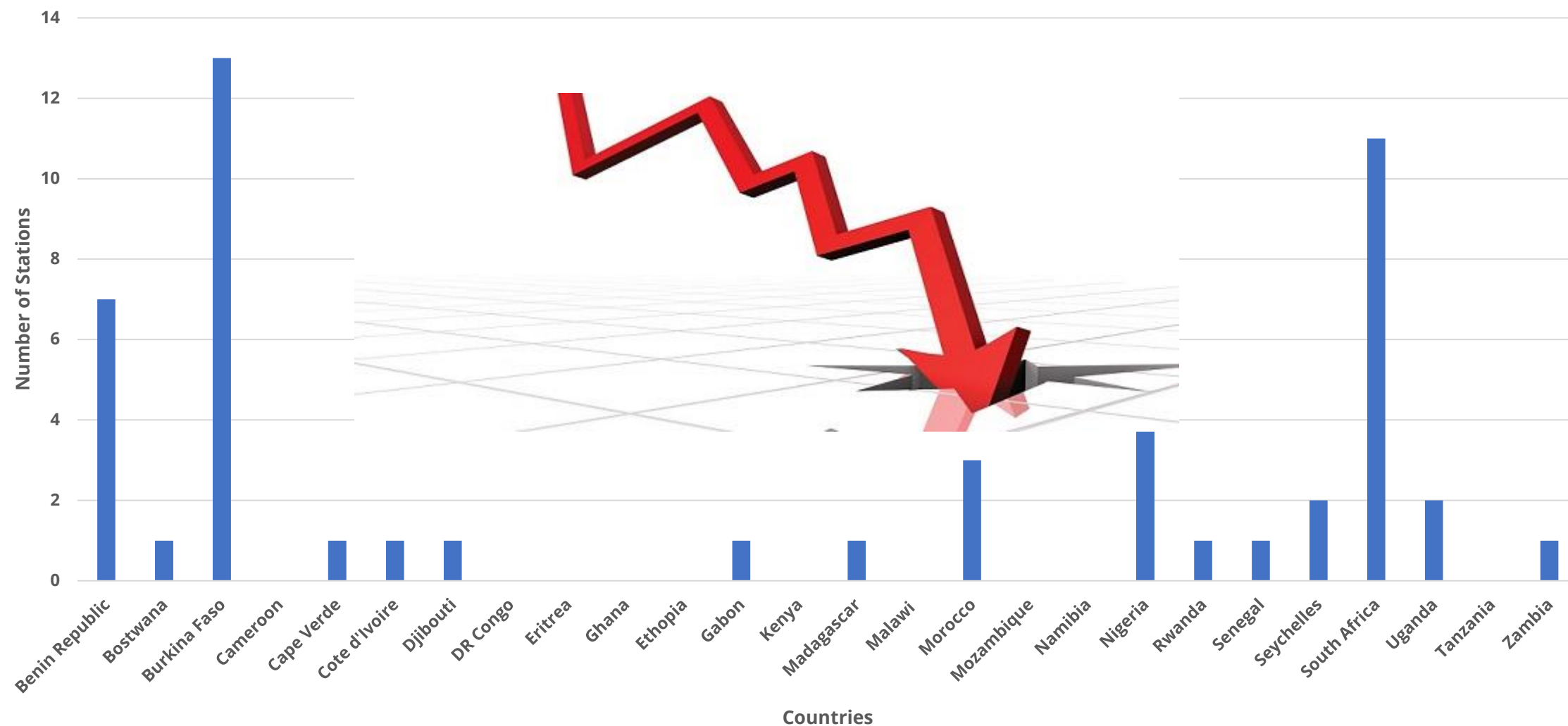


Source: <http://afrefdata.org/>, IGS and UNAVCO, July 2022

GNSS Monuments Countrywise



January-June 2022 Data AvailabilityA Decline

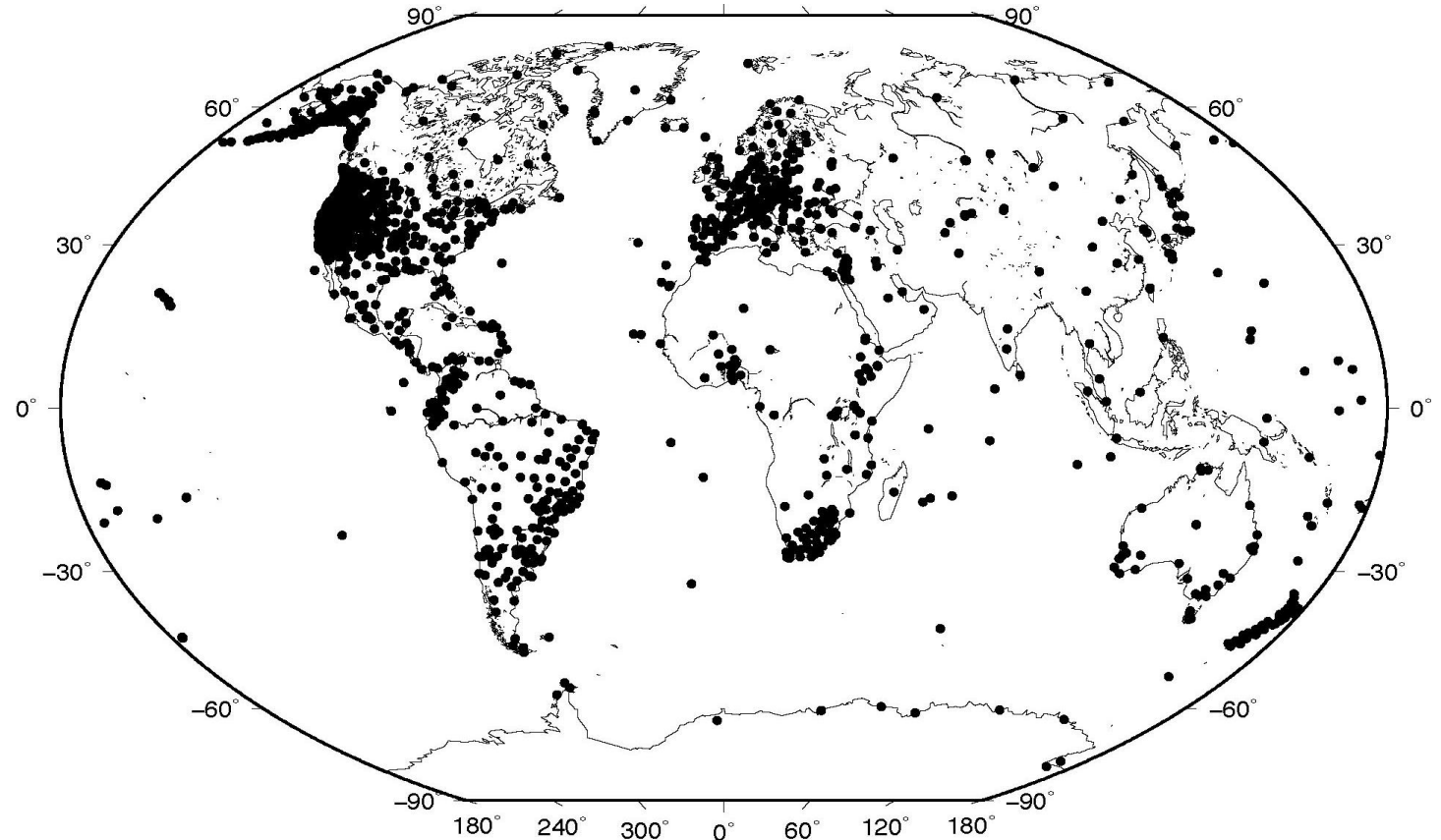


Source: <http://afrefdata.org/> and UNAVCO, July 2022

Global CGPS coverage



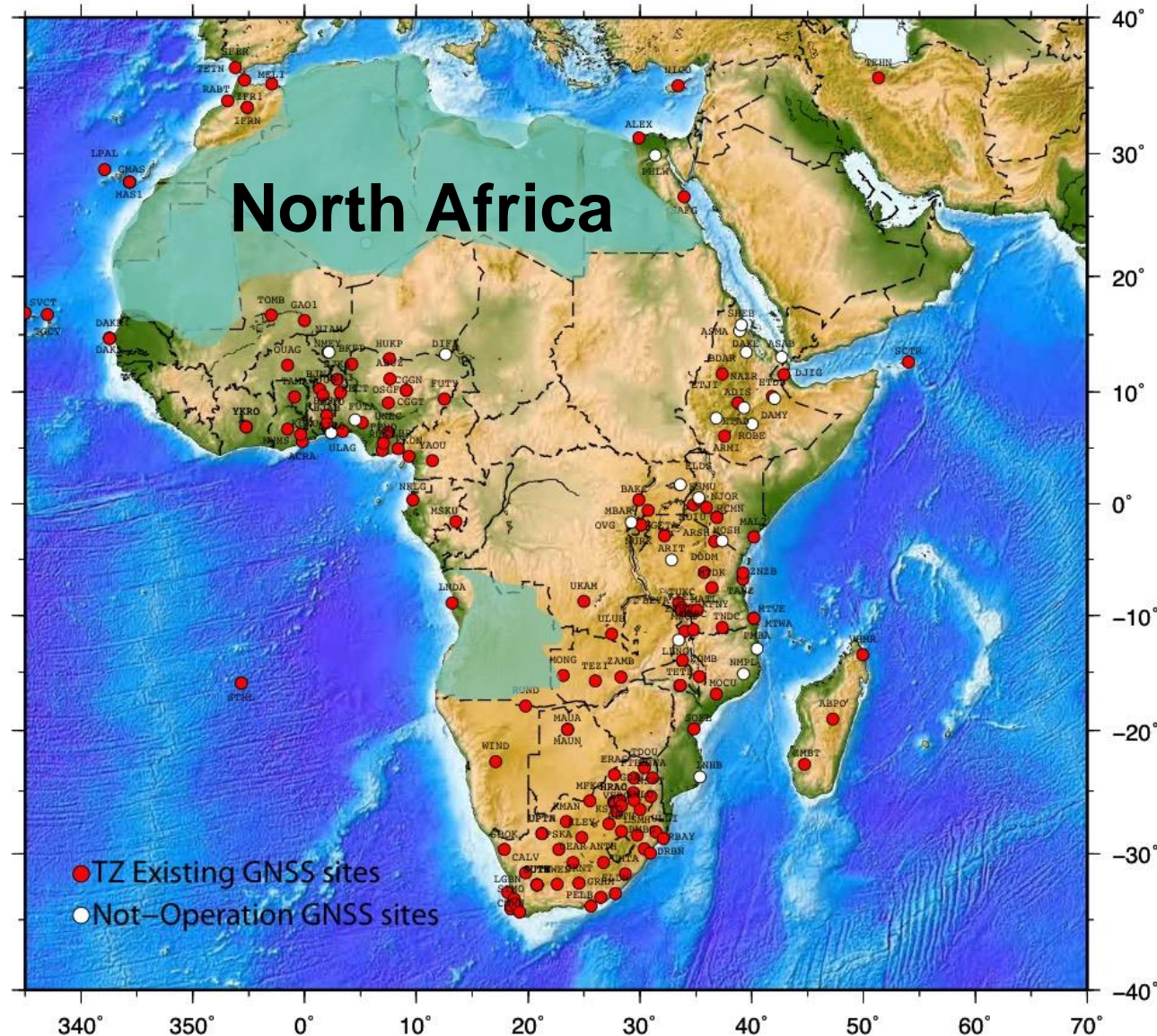
Africa Lag behind other continents



GPS Africa – Compared with other continent

Although few sites = Enough for AFREF realization?

Data Sharing



Problems

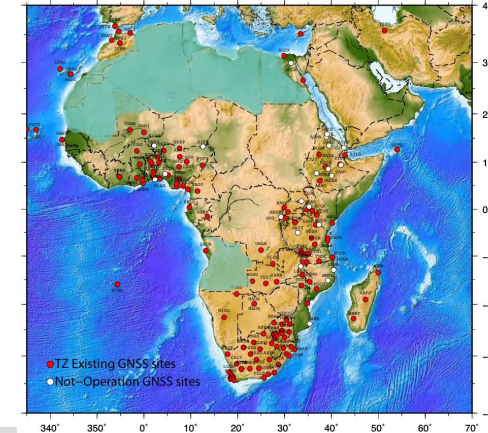
- Other countries not sharing data

Data Sharing

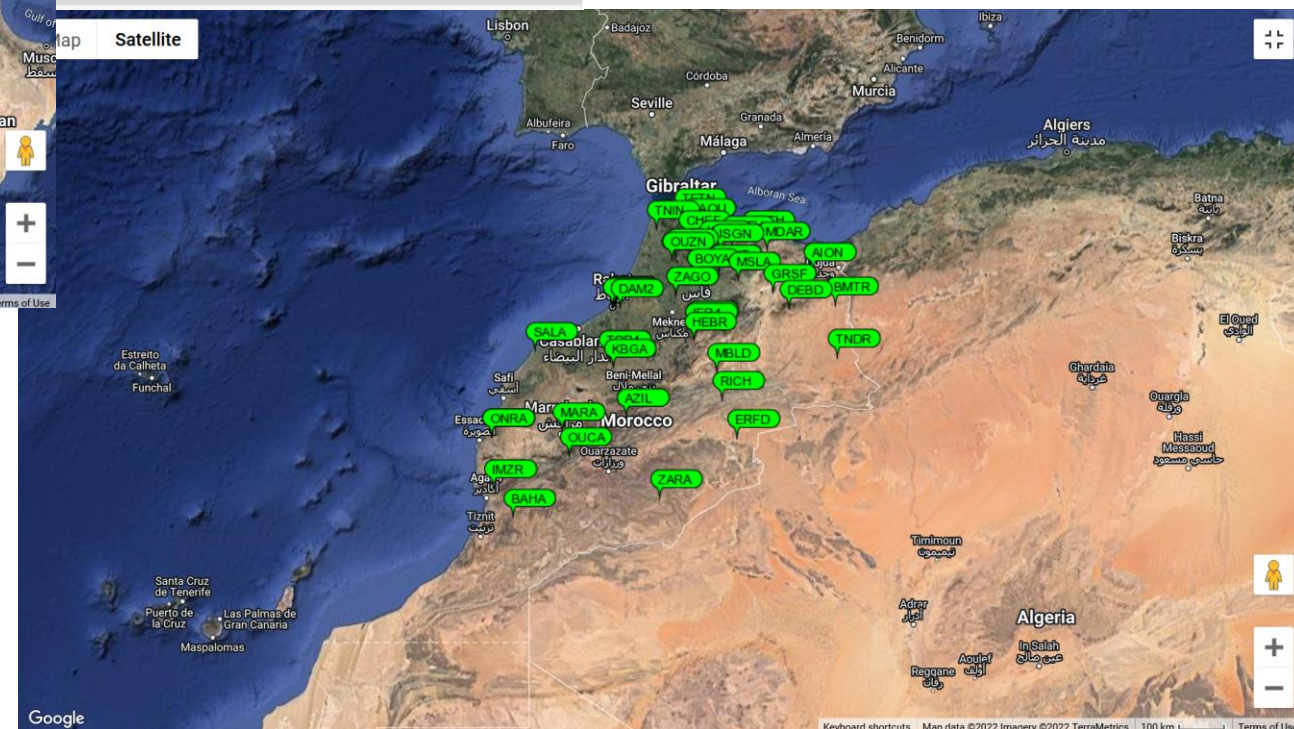
North Africa Geodetic Infrastructure



42 Monument(s) In Country: Egypt



45 Monument(s) In Country: Morocco



- Not sharing data
- Mostly Passive Stations

Not contribution to the AFREF ODC

Data Sharing West Africa Geodetic Infrastructure



Reference Data Shop - Reference Stations

Choose one or more reference stations by clicking in the list or in the map. If you want to select multiple stations from the list, press and hold down the CTRL key and click with the mouse.

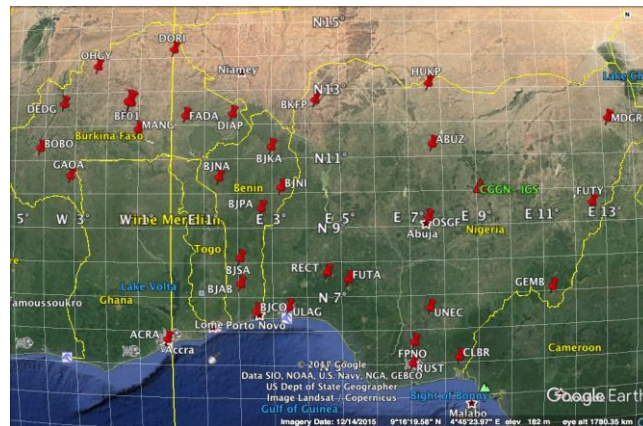
Available Reference Stations

- BF01
- BOBO
- DEDO
- DIAP
- DORI
- DPGO
- FADA
- GAOA
- IGBO
- KBRI
- MANG
- OHGY
- TGDA

All are Active Stations

Nigeria Not contributing data to AFREF

Burkina Faso Not Contributing data to AFREF



TERONET

Sign Up Login

Username Password

Sign me in I forgot my password

UTC: 2022-07-05 13:17:00

User's Manual

TeroNet v1.0.0 Copyright © 2022 Powered by: TeroMovigo - Earth Innovation, Lda.

Data Sharing South Africa Geodetic Infrastructure

All are Active Stations



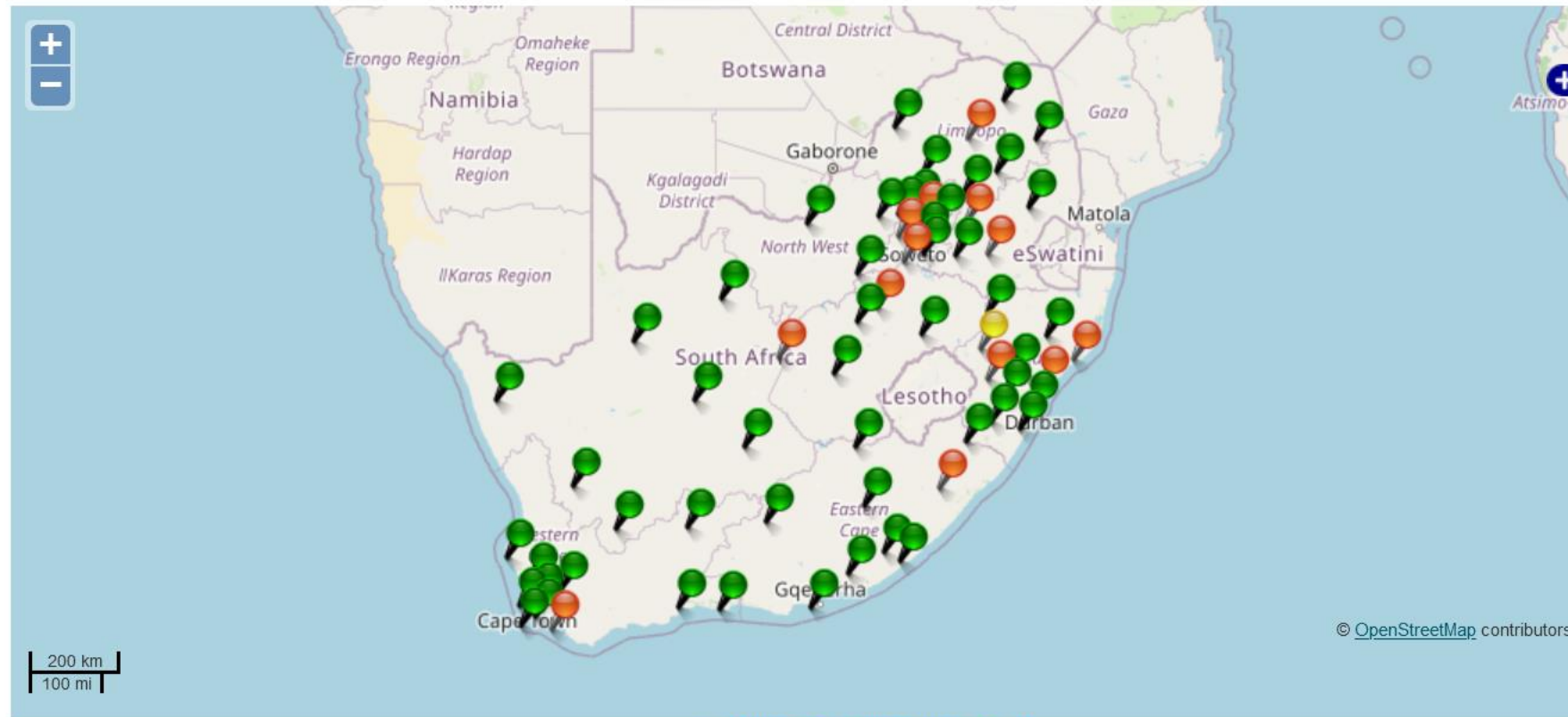
TrigNet Web

> [Home](#) > [Sensor Map](#)

- ▼ Home
 - ▶ [Sensor Map](#)
 - ▶ [Login](#)
 - ▶ [Register](#)
- ▼ External Links
 - ▶ [Trimble](#)



Sensor Map



65 sensors:

ANTH
BENI
BETH
BFTA
BISO
BRIT
BRNK
BWES
CALV
CPNT
CTWN
DEAR
DRBA
ELDA
EMLO
ERAS
GDAL
GEOB
GREY

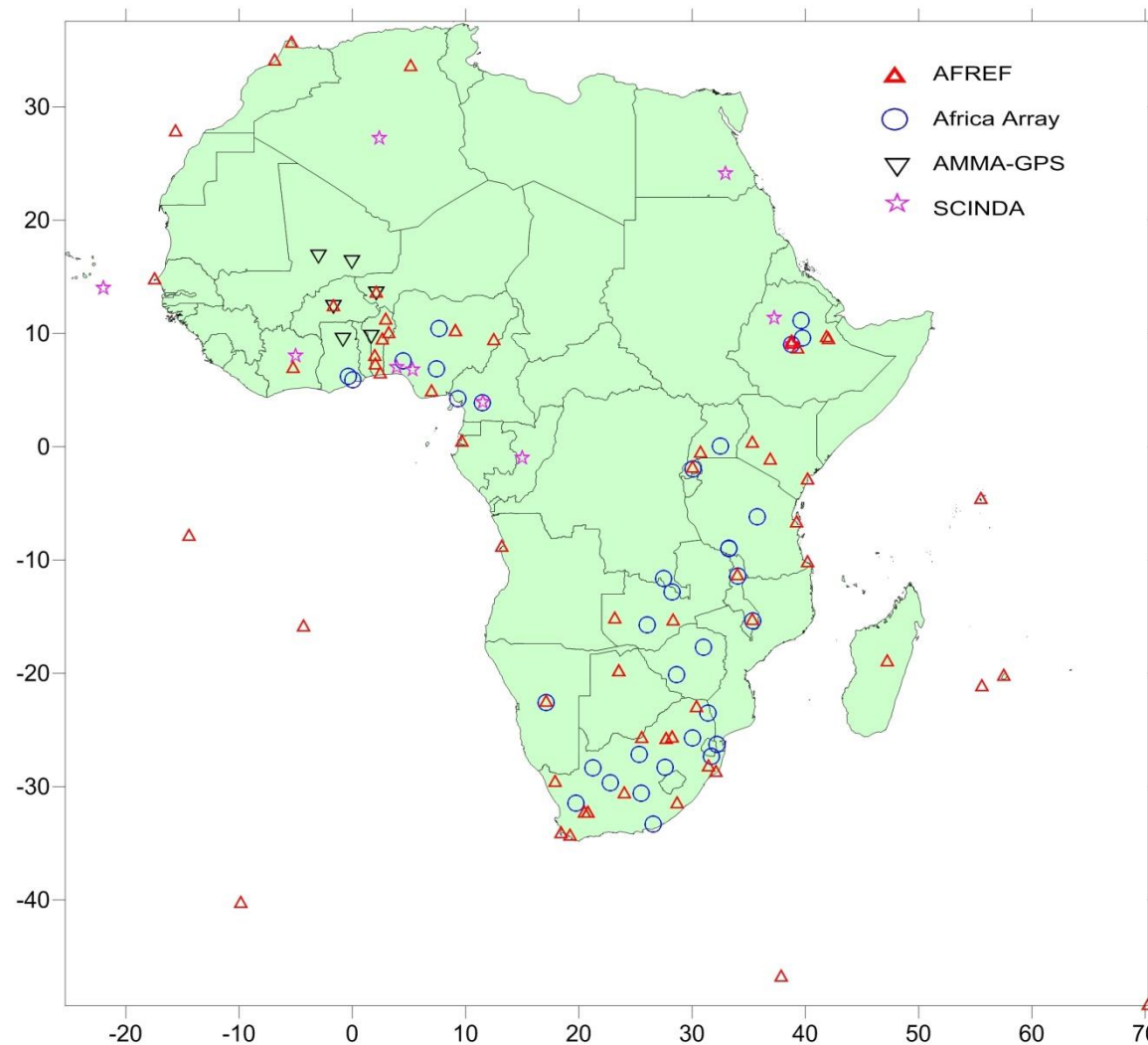
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Not all contributing to the AFREF ODC

Progress Made

AFREF Inter-disciplinary Collaboration

Geodesy: AFREF
Seismology: Africa Array
Meteorology: AMMA-GPS
Space weather: SCINDA



Progress Made

1st Static AFREF Solution



- A two week period was identified during which data from approximately 50 stations was logged:

- Week 1717 2 Dec 2012 to
- Week 1718 15 Dec 2012

- Four centres processed data from approximately 50 sites per day covering a two week period.

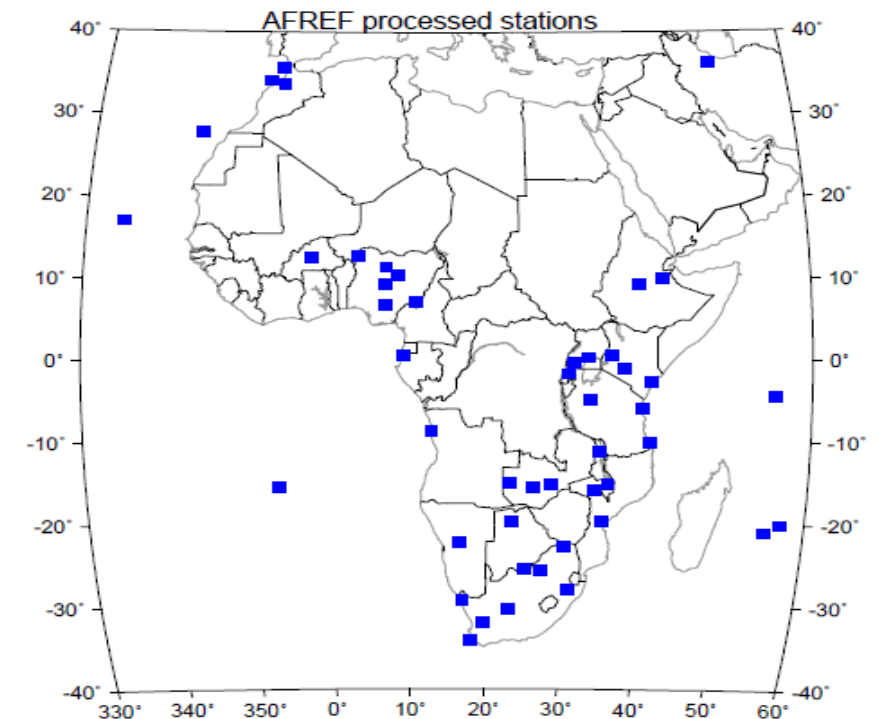
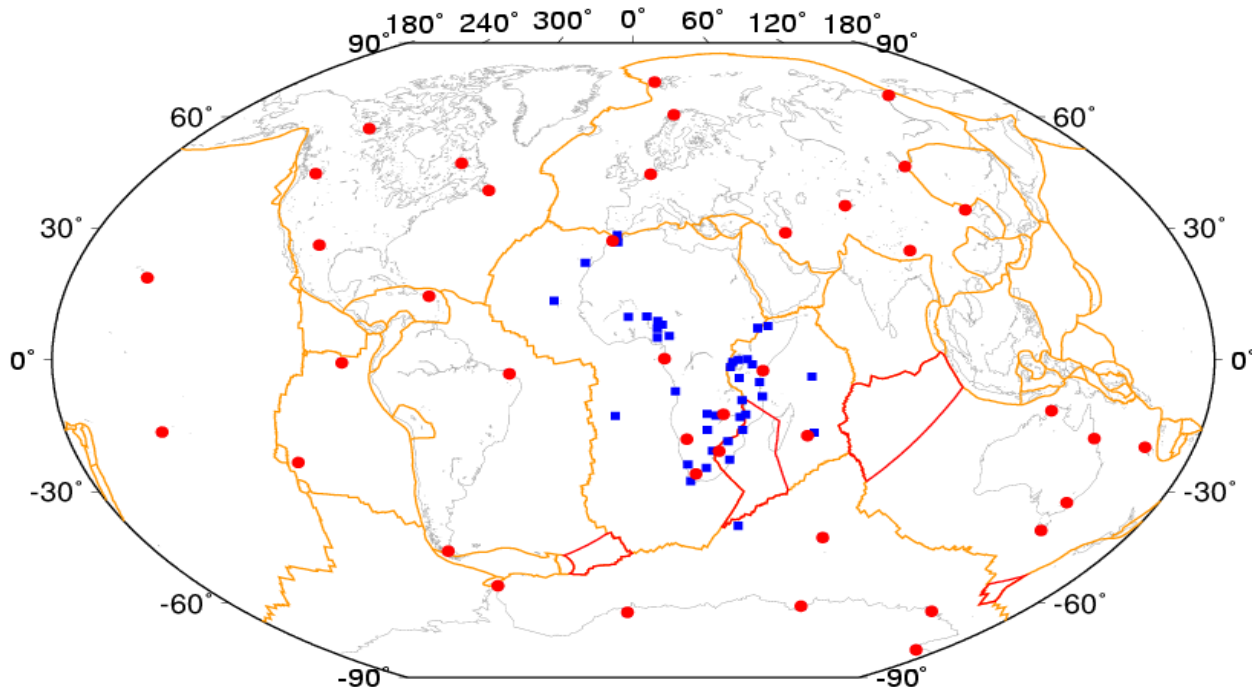
HartRAO	South Africa
SEGAL (UBI/IDL)	Portugal
Dir Surveys & Mapping	Tanzania
Ardhi Univ	Tanzania

- Final combination is was done by IGN France

Progress Made

1st Static AFREF Solution

Distribution of AFREF sites processed. Note gap from Angola through Congo, Sudan and across North Africa.



Distribution of processed sites. On average 50 sites per day for 2 weeks. Red symbol indicates sites used in the alignment to ITRF208.

1st Static AFREF Solution



Processing strategy

	Processing Centre			
	Ardhi University Tanzania	HartRAO South Africa	SEGAL (UBI/IDL) Portugal	Div Surveys and Mapping Tanzania / Australia
Software used	GAMIT / GLOBK 10.5	GAMIT / GLOBK 10.5	GIPSY-OASIS	GAMIT / GLOBK 10.5
Epoch rate	30 SEC	30 sec	30 sec	30 sec
Final Orbits	IGS Final	IGS Final	JPL Precise	IGS Final
Earth Rotation Parameters	IERS2010	IERS2010	IERS2010	IERS2010
IAU nutation model	IAU 2000	IAU 2000	IERS Conventions	IERS Conventions
Elevation mask	0 deg	10 deg	7.5 deg	10 deg
Ocean loading model	FES2004	FES2004	FES2004	FES2004
Tropo Model Dry Wet	GMF GMF	GMF GMF	VMF1GRID Estimate 2 nd order ionospheric correction	GPT2 GMF Estimate 2 nd order ionospheric correction
Ionospheric models				
Ambiguity solution	Wide-Lane LC	Wide-Lane LC	Yes	Yes
Number of stations processed				
1. Week 1717	82	80	86	86
2. Week 1718	85	79	85	86
Number of IGS control stations				
1. Week 1717	40	40	37	48
2. Week 1718	42	40	37	48
General			Tide models: WahrK1 PolTid FreqDepLove OctTid	

Progress Made

1st Static AFREF Solution

WRMS in East, North and Up, per AC and per week.

Solution	# Sta	Week 1717			# Sta	Week 1718		
		E	N	U		E	N	U
		mm				mm		
HartRAO	80	1.4	1.0	4.9	79	1.2	1.1	5.0
DSM	84	1.2	0.9	3.9	86	1.2	1.0	3.8
Ardhi	75	1.0	0.9	3.4	77	0.9	0.8	3.4
SEGAL	87	1.3	1.7	6.7	85	1.3	1.8	6.0

Preliminary Results

WRMS values of the alignment to ITRF2008 using 42 reference stations, which are in East North and Up in mm, respectively :

	E mm	N mm	U mm
Week 1717:	2.9	3.2	7.4
Week 1718:	3.0	3.4	7.6

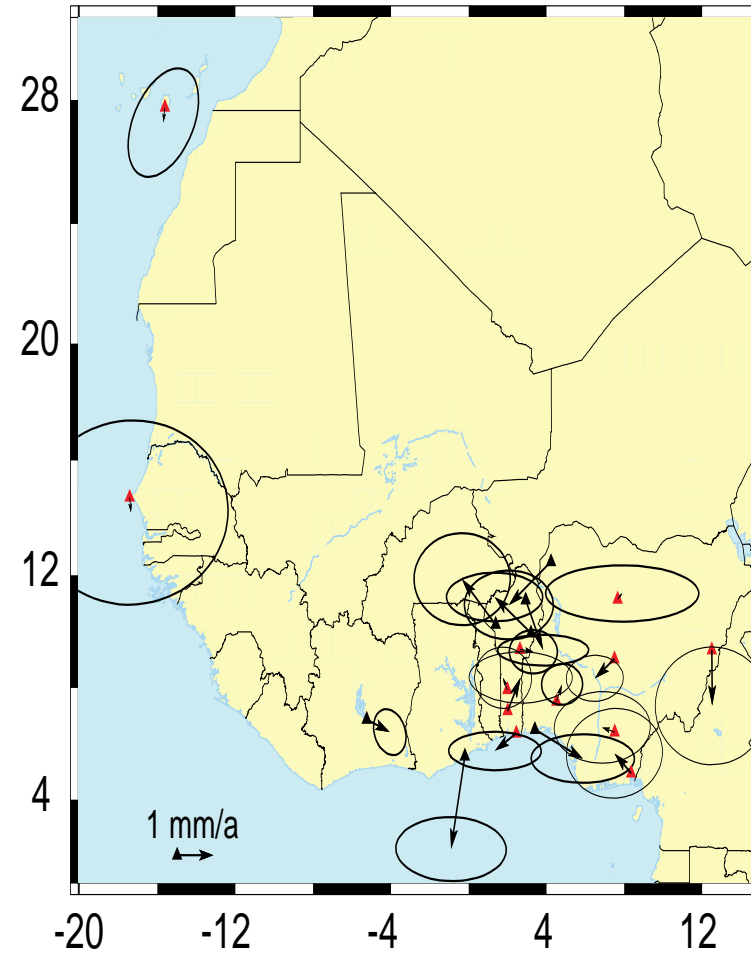
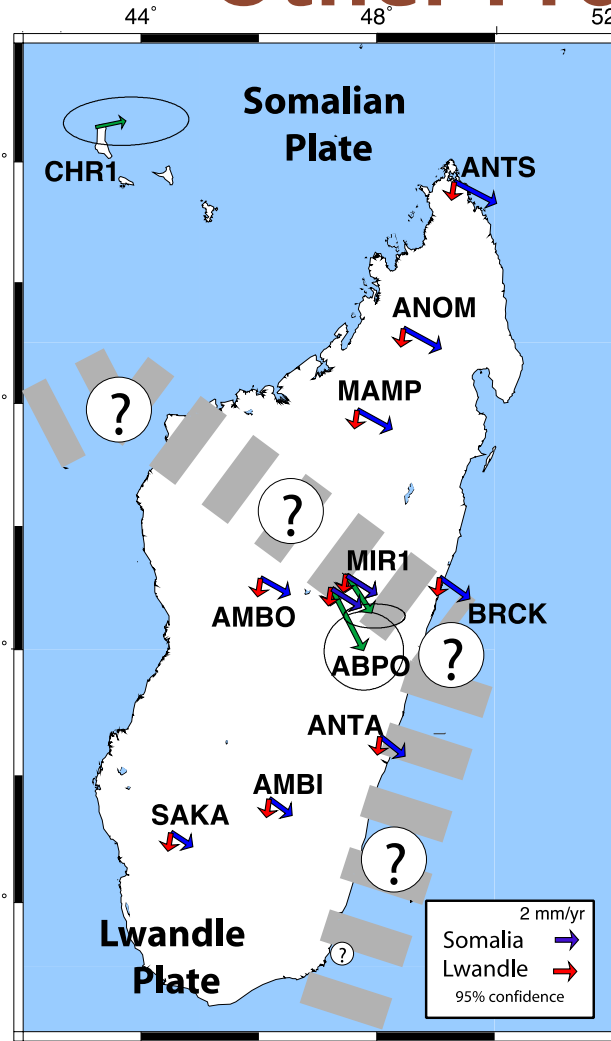
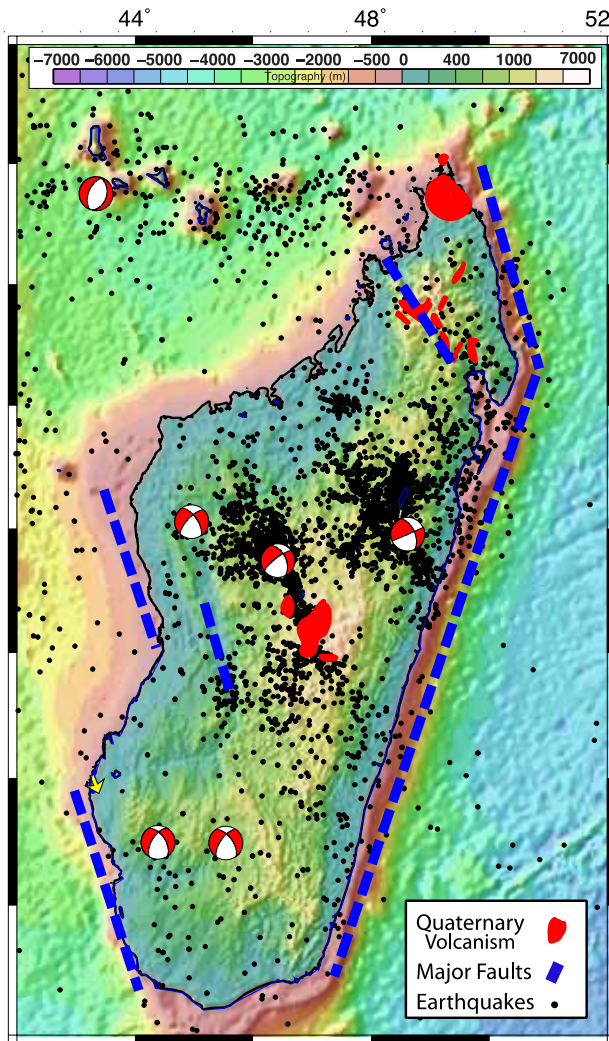
Other Progress Made



Using ~70 Sites
on Nubia
A.Vel for West
Nubia
Compared to
Central and
South Nubia

No Sites in
Algeria Tunisia,
Libya and others

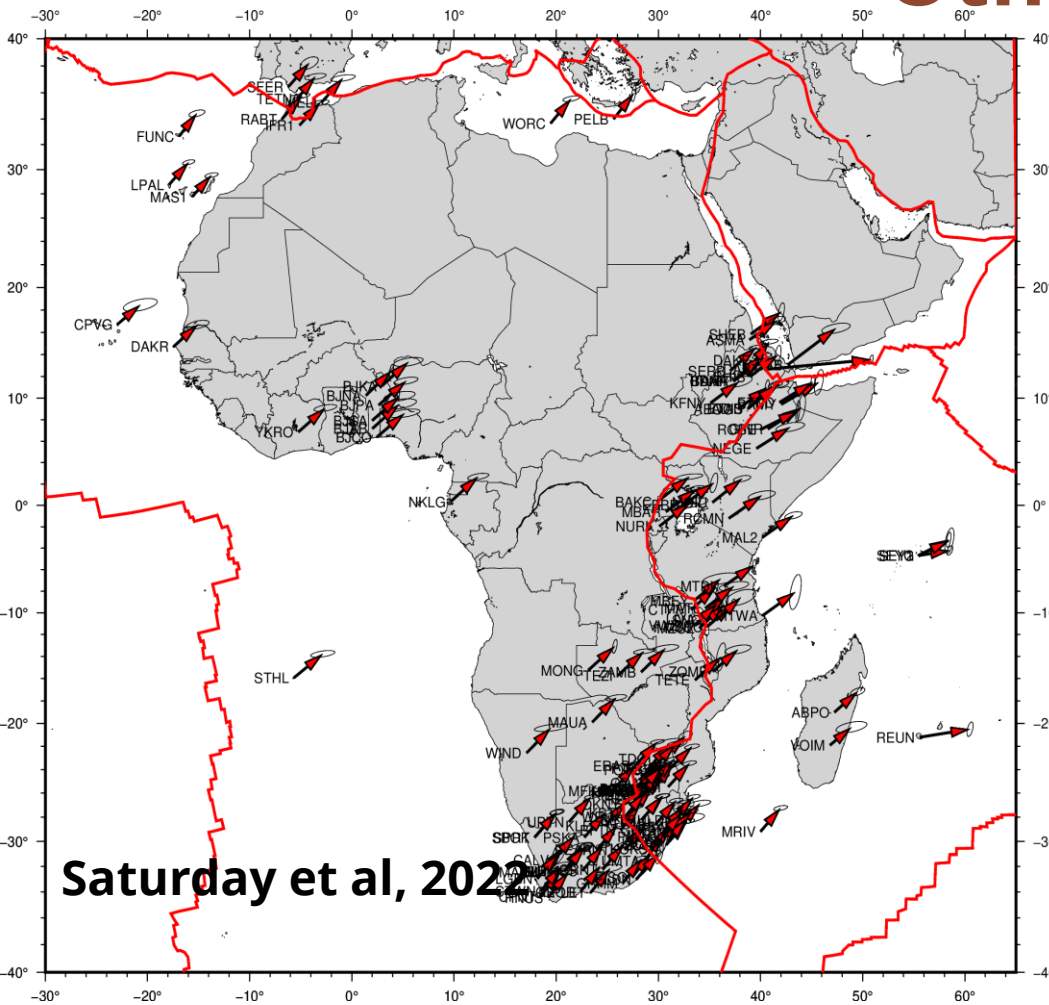
Njoroge et al., 2015



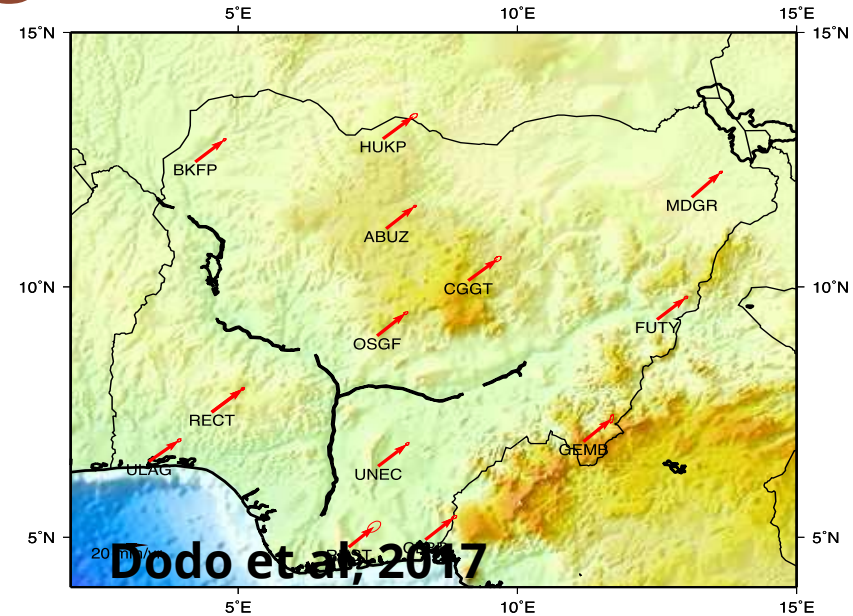
Some Effort from Madagascar

Sarah Stamps + G. Rambolamanana – Episodic + Continuous

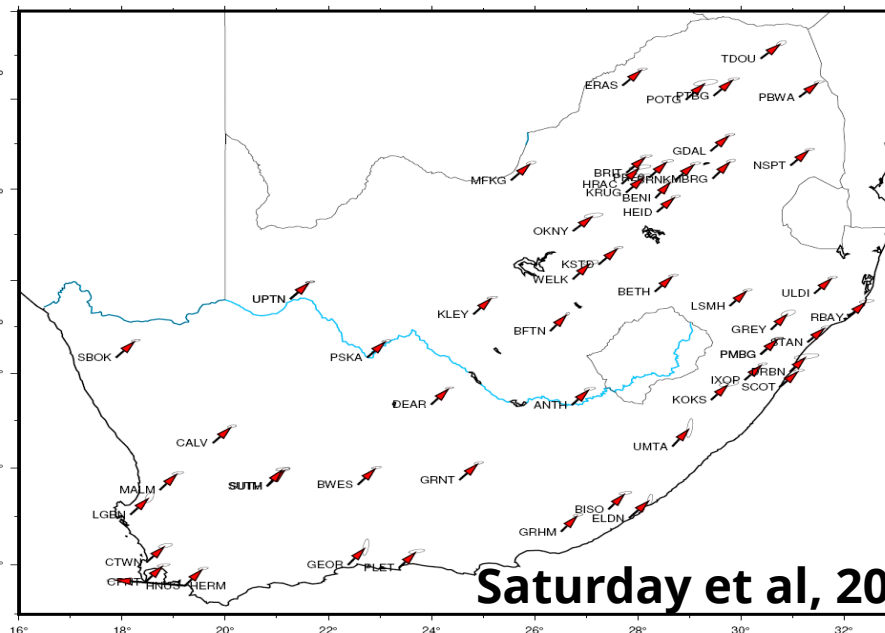
Other Progress Made



Saturday et al, 2022

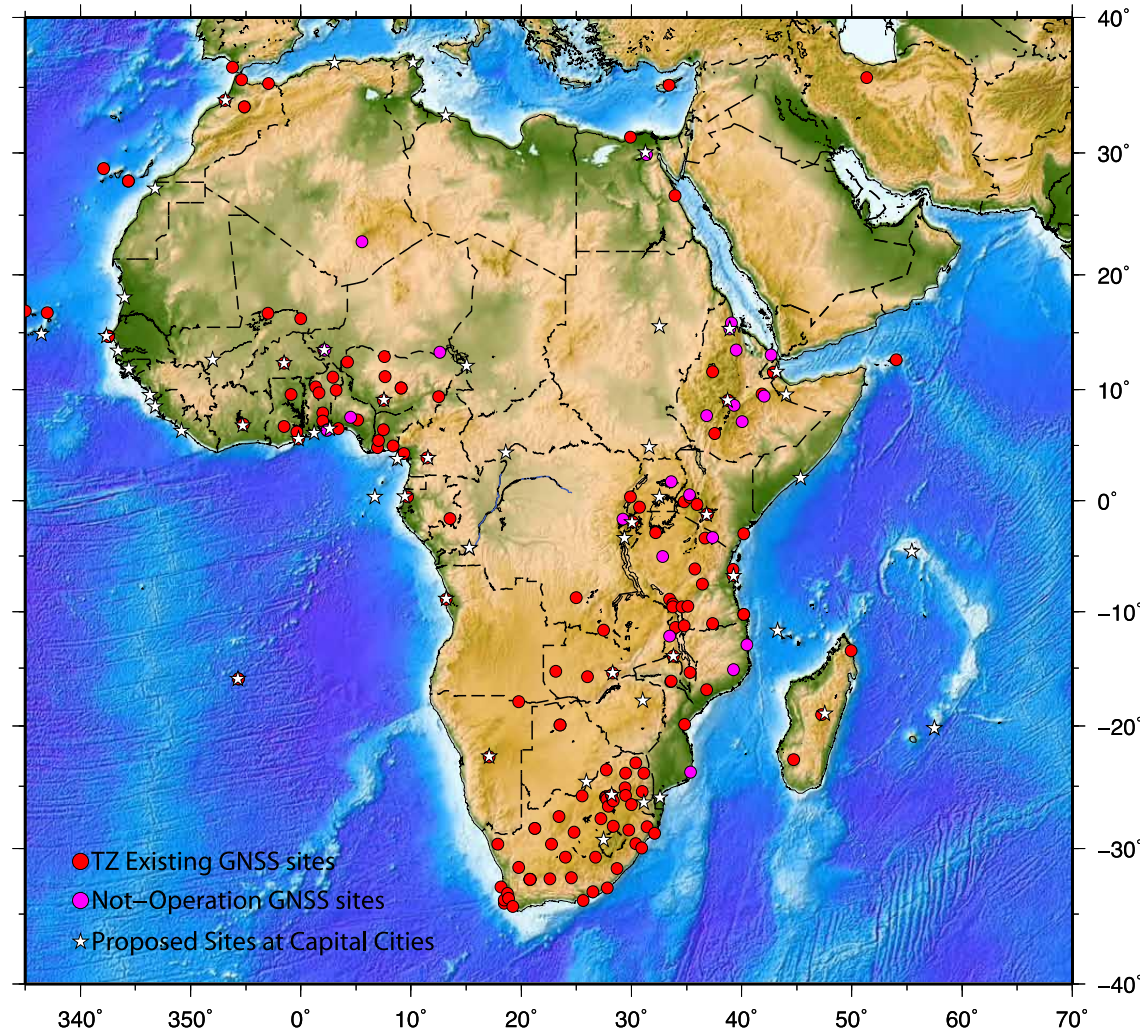


Dodo et al, 2017



Saturday et al, 2022

Optimum Location of New GNSS Site for AFREF



Establish CORS

such that each **nation** or each user has free access to, and is at most 1000km

= What if Each capital city host CORS site? = Only for Countries with NO CORS

Problem – Some Capital City may be at boarder with another country

What if we consider the Central cities for each country??

Optimum Location for new AFREF stations



AFREF Criteria

- Establish CORS - each nation or each user has – Access at most 500km

Muzondo (SA –Scholar) (Muzondo et al., 2015)

- Used ArcGIS – tool
- Used Voronoi Polygon based on existing points
- Technique to include or exclude countries that met or did not meet AFREF criteria
- Challenges = Some countries Area size were smaller than AFREF Criteria = Flagged for further analysis as possible regions which fail to meet AFREF minimum requirements.
- Some Islands were also included with only one site even for larger Island e.g. Madagascar

Optimum Location for new AFREF stations



Failure of the method

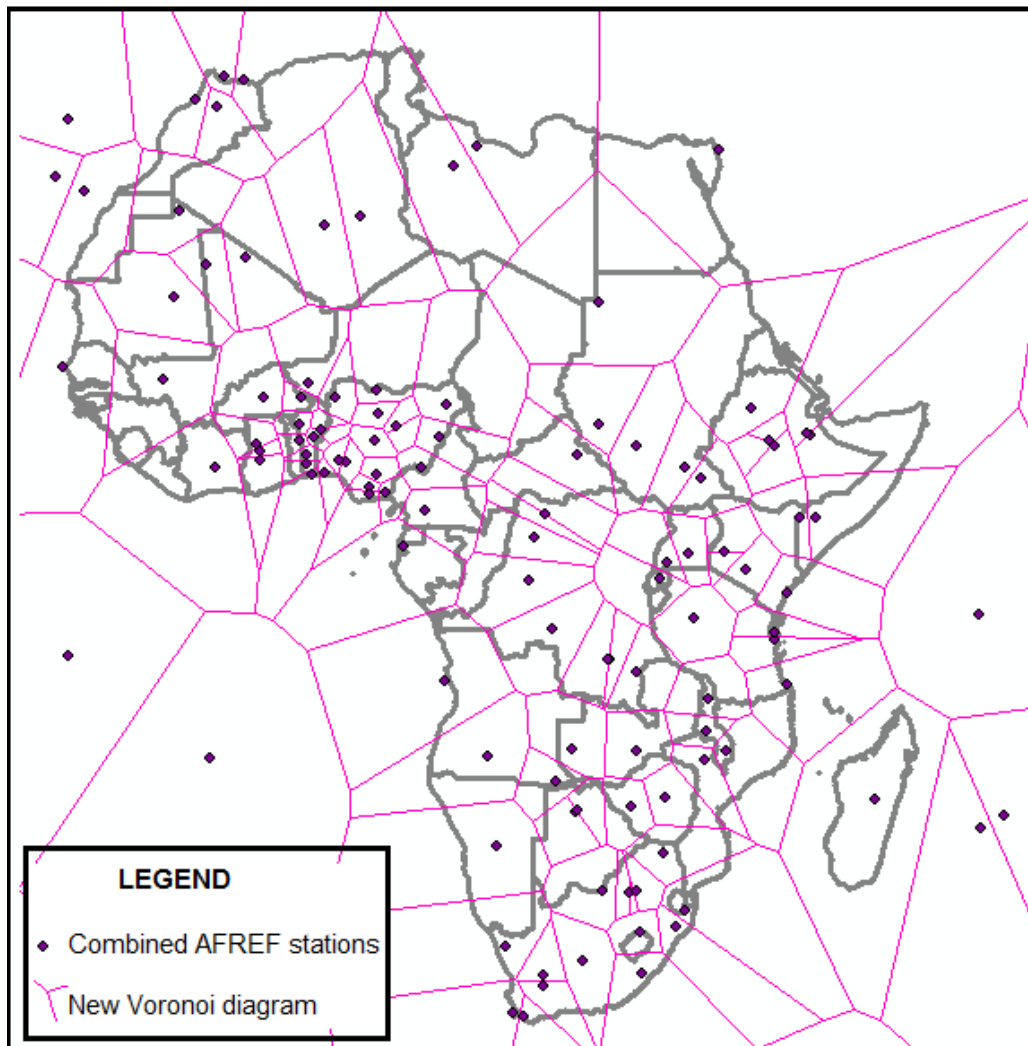
Initial results had ~636 candidate GNSS stations. This number was too high for Africa to construct in the next 10 years, considering that approximately 84 stations were constructed in the last 12 years.

Some candidate GNSS stations fell too close or duplicated the existing candidate GNSS stations, particularly in areas where adequate GNSS stations already exist.

Remedy

To comply with minimum AFREF requirements, candidate stations remain mandatory in the remaining African countries that currently do not host permanent GNSS stations.

Optimum location of New GNSS site for AFREF

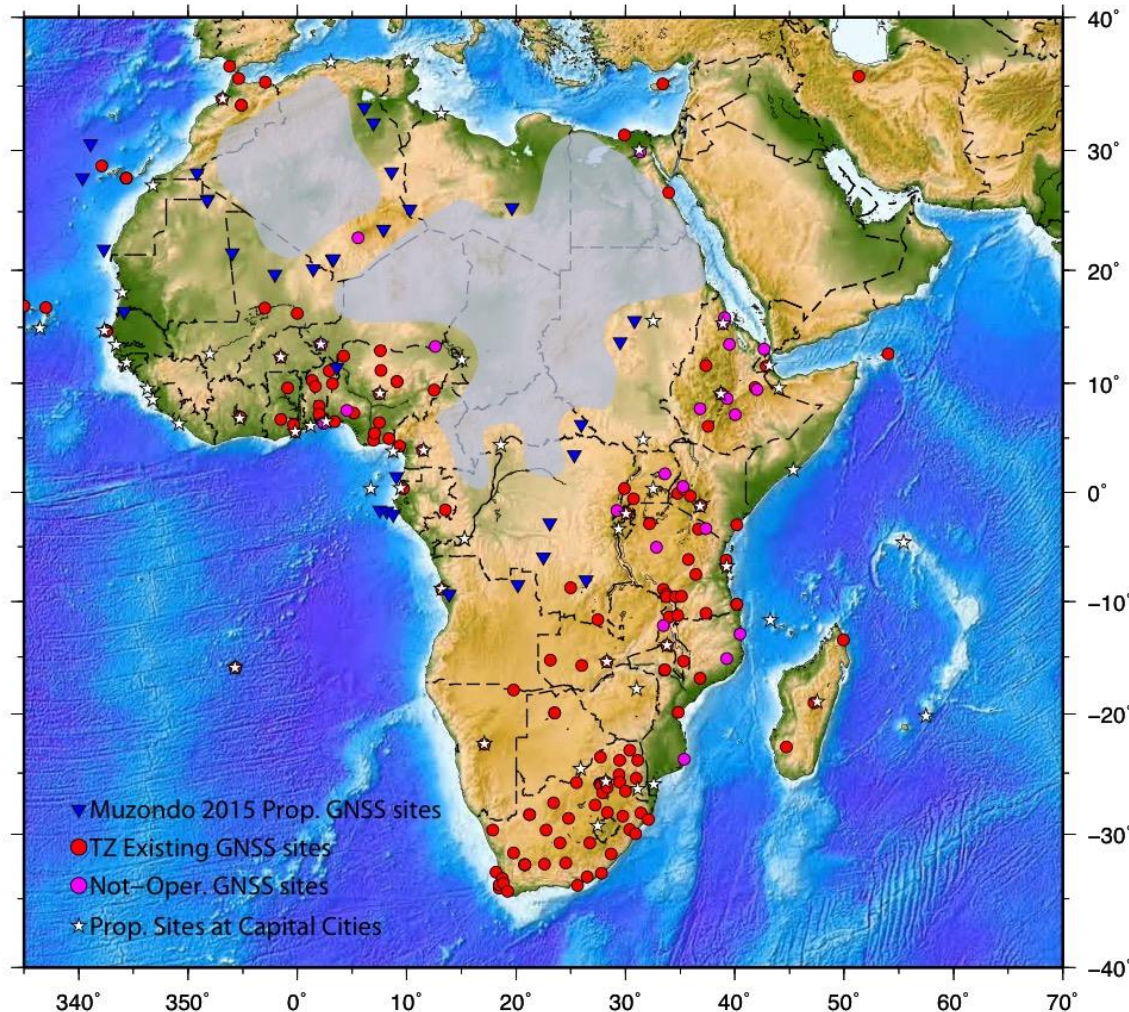


Thus the Number of GNSS sites were scaled down to 35

Works well for some Countries
Other country not very good
Eg Algeria, Egypt, Libya, Madagascar, Somalia, Central Africa etc

Muzondo et al., 2015

Optimum location of New GNSS site for AFREF – Combined Muzondo and Capital Cities



Some Gaps are still observed

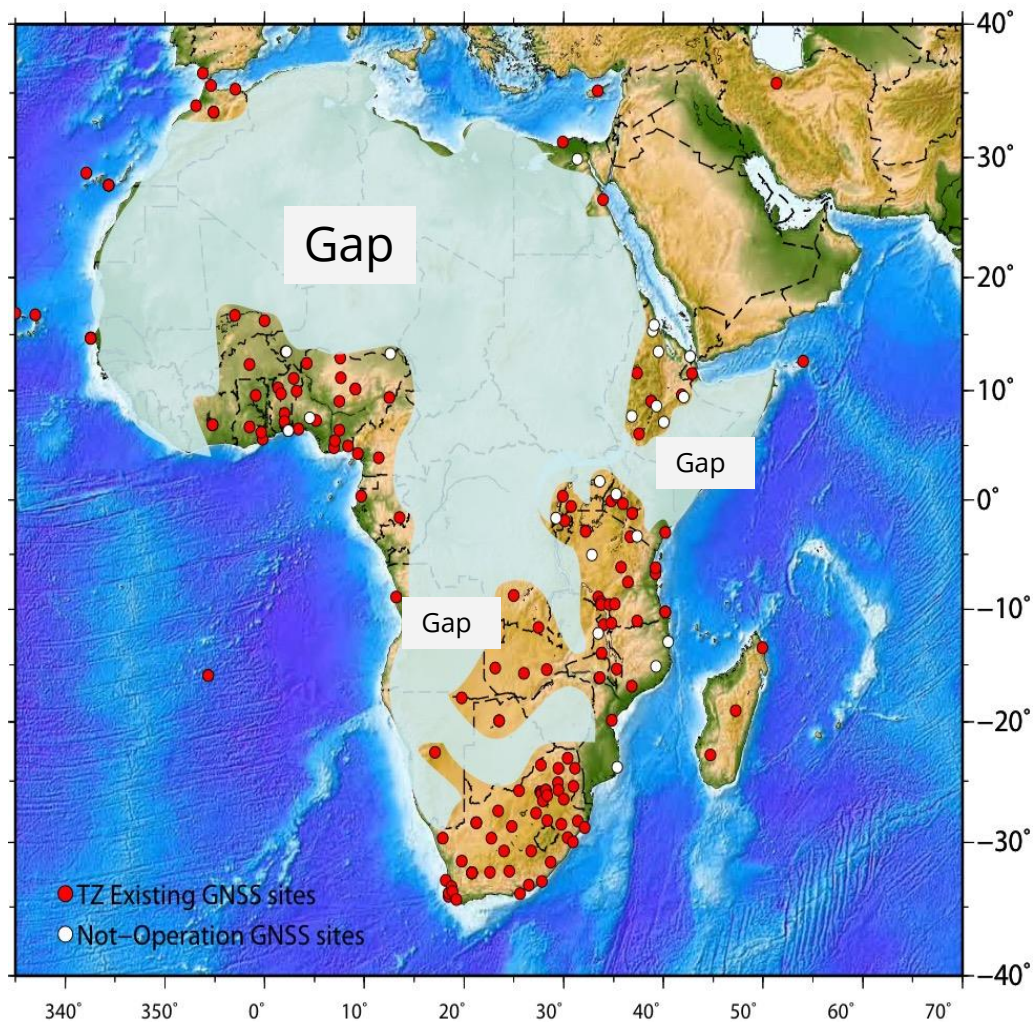
Some countries are not spatially covered well

Some Sites are located close to each other

Still No Solution

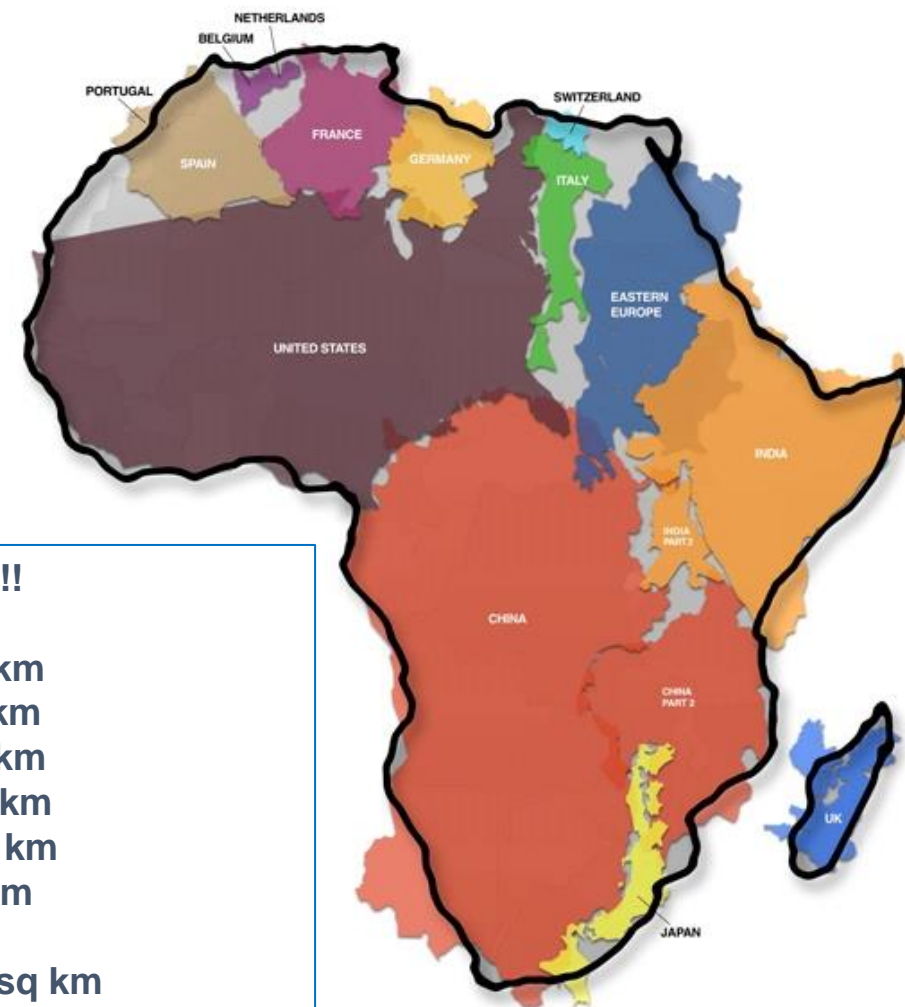
Solution on this should be left for debate

Challenges



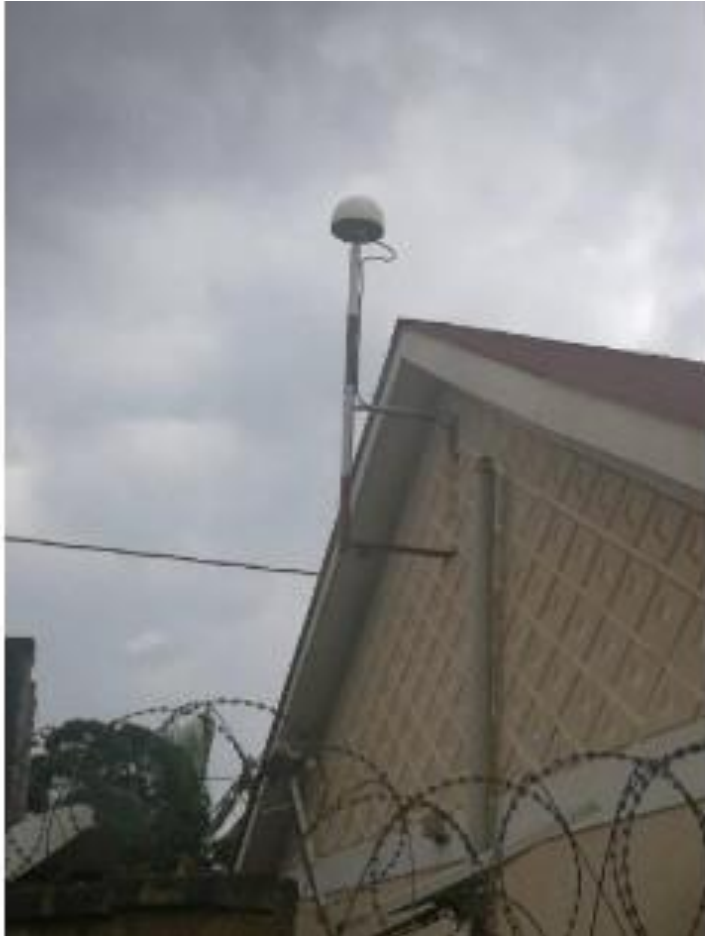
Africa is BIG!!

China	9596915 sq km
USA	9372570 sq km
Europe	4933927 sq km
India	3280465 sq km
Argentina	2758826 sq km
New Zealand	268674 sq km
Total	30 211 377 sq km
Africa	30 321 130 sq km



1. Insufficient Geodetic Infrastructure
~50% of Africa no GPS sites

Challenges



2 . Selection /Installation

- Standards not followed in some cases (IGS Standards)
- Among the Practioners

Challenges



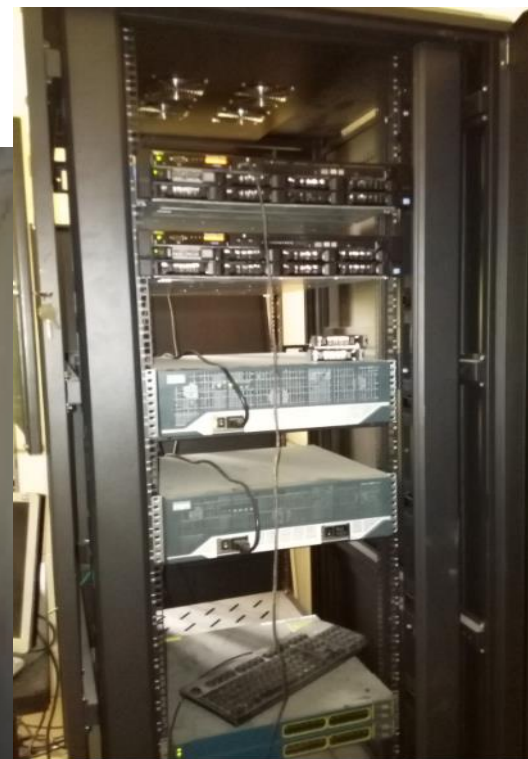
3 . Unreliable Internet and Electricity

Challenges

4. Capacity Building



Data Processing and Analysis



Data Centre Operation

Challenges



5. Data Policy

- Lack of Data sharing

6. Apparent lack of enthusiasm for project by NMA's

- Lack of understanding?
- Lack of resources – capacity and financial?

7. Political buy-in

- Again lack of understanding of benefits?
- Geodesy, Reference Frames etc doesn't buy votes!
- AFREF talks a technical language

6. Political buy-in Kwoi Earth Tremor = 2.5



6. Political buy-in The 2018 Abuja Earth Tremor =3.0



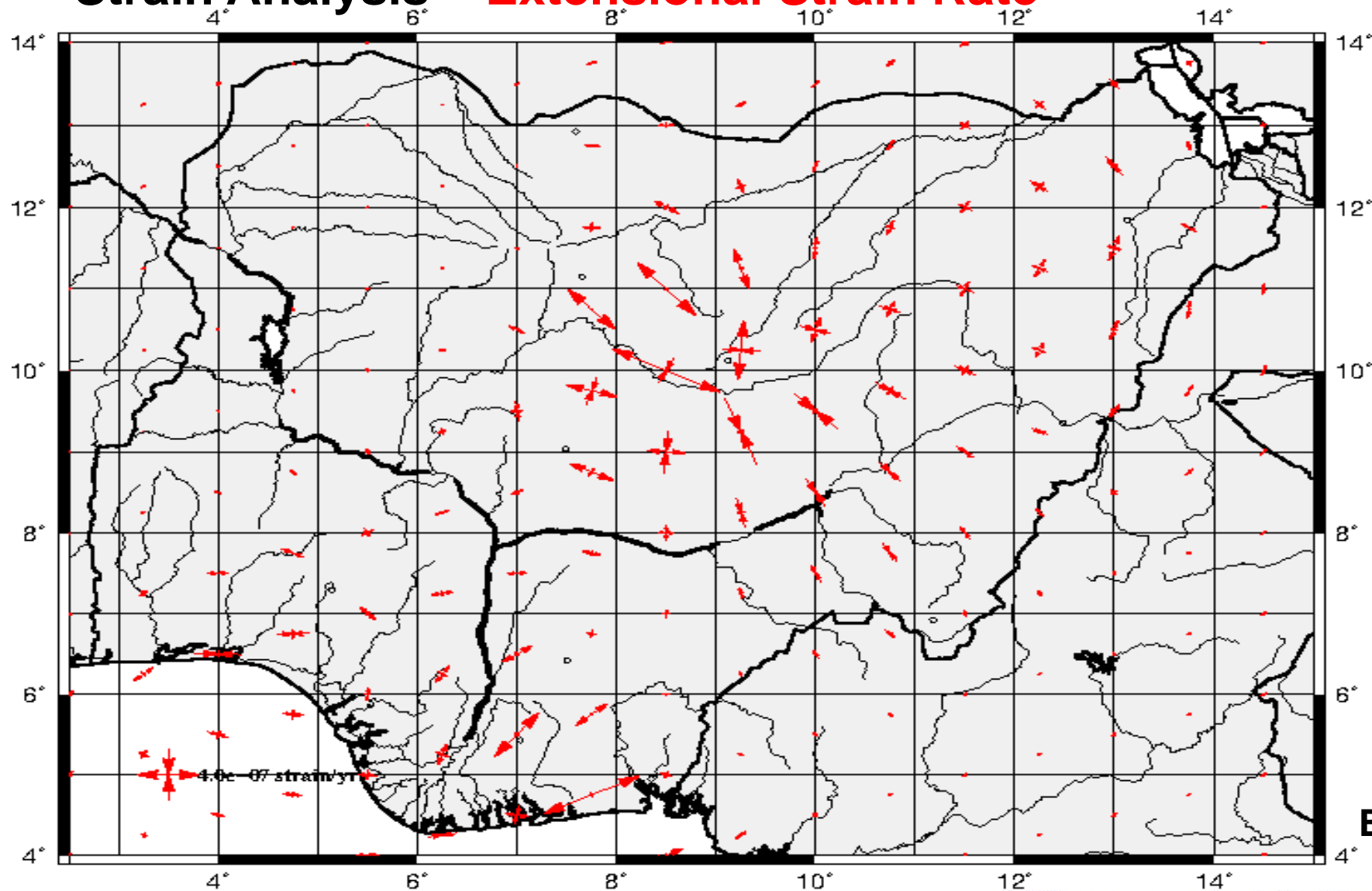
- A sequence of foreshocks were observed from 5th to 6th of September.
- The main earthquake and aftershocks occurred on 7th September 2018
- The magnitude of the main earthquake is 3.0 located at Mpape
- The length of the fault displacement was 0.56km
- No observed damages to lives and properties

(Source: Technical Report on Abuja Earth Tremor, 2018)

6. Political buy-in The 2018 Abuja Earth Tremor =3.0



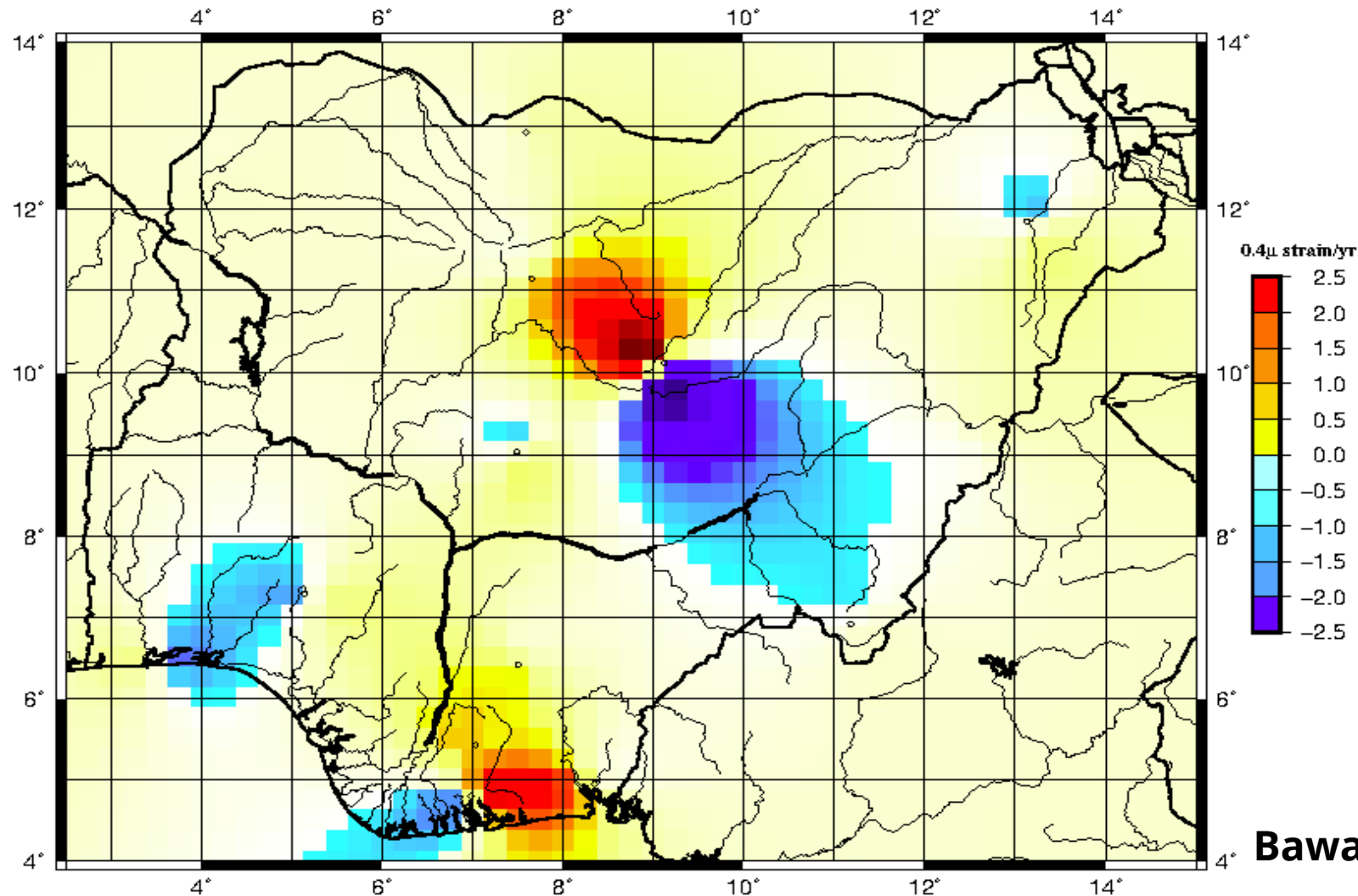
Strain Analysis – Extensional Strain Rate



Bawa et al, 2018

6. Political buy-in The 2018 Abuja Earth Tremor =3.0

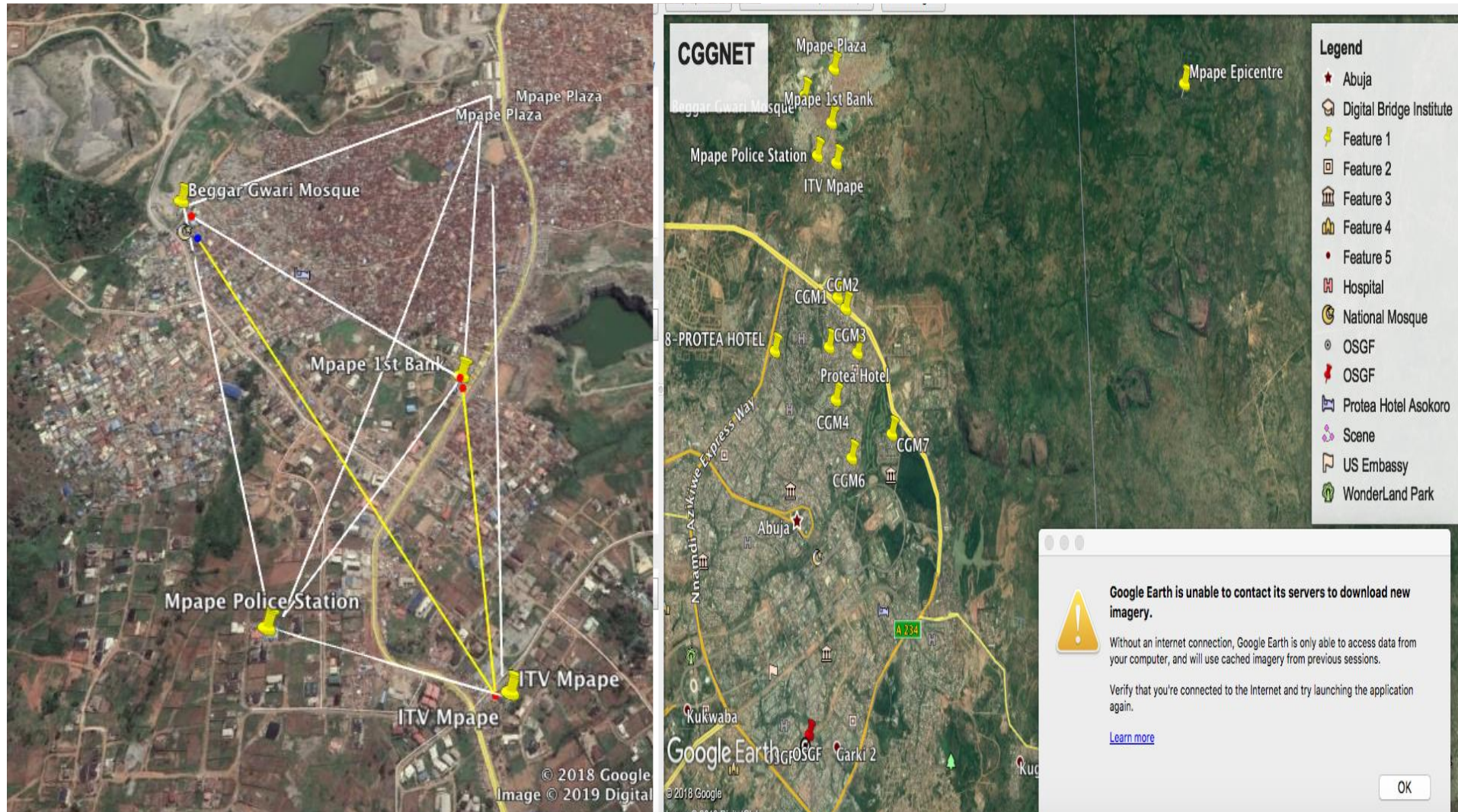
Strain Analysis – Dilatation Rate



Bawa et al, 2018

6. Political buy-in The 2018 Abuja Earth Tremor =3.0

Network of GPS Monitoring Stations: Campaign and Active Stations



6. Political buy-in The 2018 Abuja Earth Tremor =3.0

Public Comments

- **Senator Dino Melaye @dino_melaye** “I have informed the FCT Minister and Perm Sec. on the scaring earth movement in some parts of Abuja at 6:11am. I felt earth tremors in my home in maitama too. Measures are been taken to address the problem. I will keep the FCT administration on their toes on this.”
- **KinG NomSo @ani_nomso** “Father Lord these things going on in Abuja better not be an Earthquake have mercy onus”
- “The earth tremors in Abuja is the handwork of desperate corrupt people “

Source: Daily Trust Newspaper Reports 8th Sep 2018

6. Political buy-in The 2018 Abuja Earth Tremor =3.0 Current Situation



**Government
is again
Silent**



Conclusion



- Progress has been slow.
- Co-operation with other disciplines has been of benefit to AFREF and the co-operating disciplines BUT;
 - Greater co-ordination required between countries and especially participating disciplines;
 - Greater collaboration is urgently required with African Research Institutions
- CORS gap in Africa exceed 50%, Nubia and Lwandle plate mostly affected.
- Different methods can be used to determined Optimal Number of GNSS to meet AFREF criteria- Only countries with no permanent GNSS sites are considered – **Still left – Open question**
- Determining Optimal Location is one things – Maintenance is another thing, “Who is willing to facilitate”- **Open question**
- Some countries with CORS are not sharing data – Burkina Faso, Angola etc

Recommendations



- In spite of recent progress on GNSS site distribution, Africa remains largely under-sampled.
 - So we argue to open access GPS data example Burkina Faso, Angola, Mozambique, Egypt etc.
- Territories with No CORS to be convinced to host one or two at Cities where can be maintained
- **We need collaborations/MoUs: Infrastructure, Training etc.**

Thank You

