Development of the Palestinian National Geodetic Framework (PAL-GRF) Project

دولة فلسطين
سلطة الأراضي

Technical Presentation

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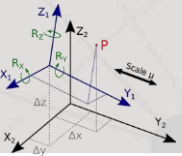
Eng. Omar Abu-Sharar

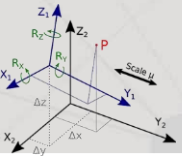
Why PAL-GRF2023?

Eng Omar Abu Sharar



Introduction (Objectives)

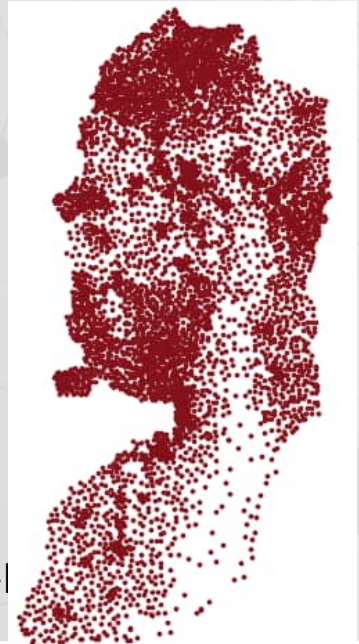
- Enhances the accuracy and reliability of geodetic and real estate data.
- Forms the core basis for any site-related engineering works.
- Essential to establish a **modern national geodetic infrastructure** for producing **up-to-date and accurate survey and topographic maps**.
- Enables systematic recording of all spatial information: Facilitates integration into Map production, Land information systems, Surveying works, Geographic Information Systems (GIS), Other geospatial data projects
- Data derived from geodetic networks is **fundamental for GIS development**.
- constitutes a **major part of the National Spatial Data Infrastructure (NSDI)**.

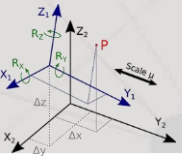


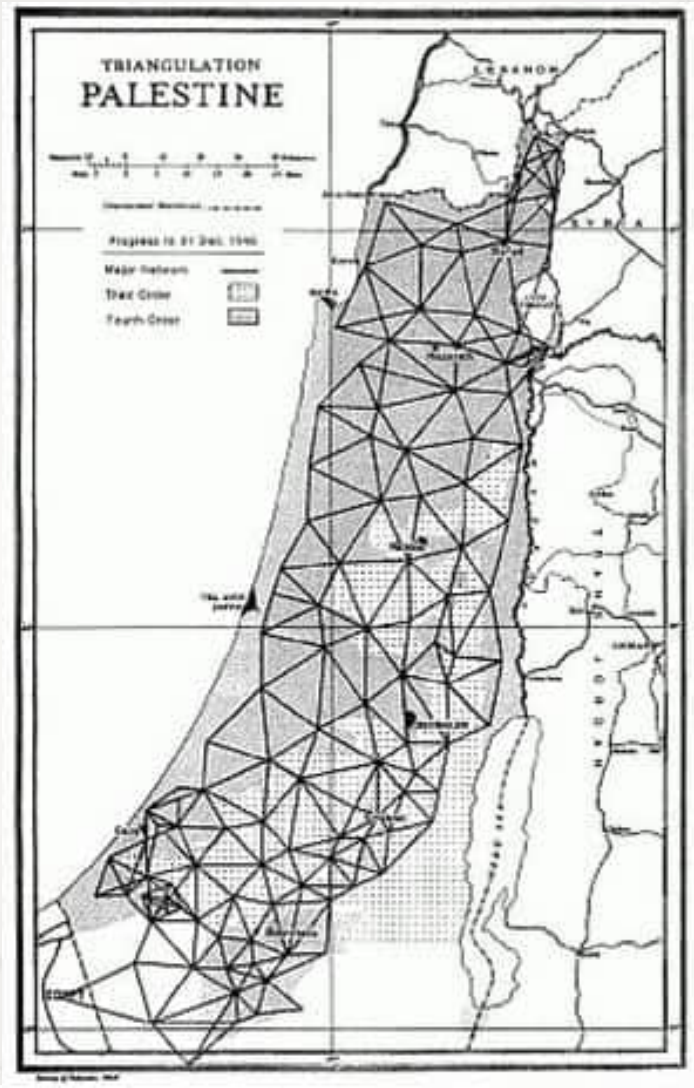
Classical Local Geodetic Networks Locally defined for local surveys

Palestinian Geodetic Network
1923-1947

2D Coordinates
Latitude/Longitude: ellipsoid
Easting/Northing: Plane

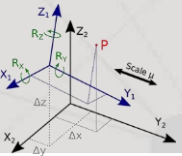






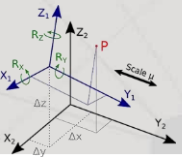
Current Issues:

- Networks do not meet modern accuracy standards.
- Low location accuracy and destruction of many points.
- Outdated, inconsistent, and error-prone geodetic networks.
- "All available geodetic networks in Palestine are outdated, inconsistent, and cause significant and unorganized errors."
- Crustal deformation alters point positions over time in the region.



Why Pal-GRF2023

- An Intermediate system between : Kinematic positioning (Satellite Orbits , tectonic Plates) and static positioning (Land/engineering surveying)
- High level of accuracy (mm-cm): compatible with GPS/GNSS Positioning, Drone Photogrammetry, and Laser Scanning.
- A unified official system to be used for all kinds of surveys.
- Unified method for converting coordinates and maps .
- Suitable for establishing or re-establishing GNSS continuous operating points and services (CORS).
- Suitable for local, regional and global positioning.



Modernizing the Geodetic Reference Framework

1.Objective of the Update:

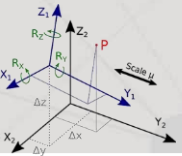
1. Address the issue of using outdated references for surveying and mapping despite changes.
2. Modern geodetic infrastructure is designed to provide accurate, reliable, and rapid geospatial data.
3. Ensures compliance with precision standards for 3D coordinates (including physical elevations) and their changes over time.

2.Analysis of Current Palestinian Geodetic Infrastructure:

1. Evaluated in terms of tasks, methodologies, and technology.
2. Decision made to establish a modern geodetic infrastructure.

3.Outcome:

1. Enables precise positioning for all users across all aspects.



Concepts

1.Geodetic Definition:

1. Determines geometric coordinates relative to Earth's geometry.
2. Measures physical elevations relative to Earth's gravitational field.

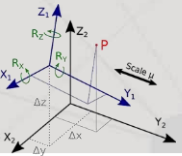
2.PAL-GRF (Palestinian Geodetic Reference Frame):

1. Linked to the **International Terrestrial Reference Frame (ITRF)**.
2. Approved by the **International Union of Geodesy and Geophysics (IUGG)**.

3.Purpose of PAL-GRF:

1. A network of points with four-dimensional positions (X, Y, Z, time).
2. Monumented and maintained for reliability and ease of use.
3. Ensures alignment with national and international reference frames.
4. Outcome: Provides coordinates (X, Y, Z) and latitude, longitude, and height based on ITRF.

- **Integration with the international community**:
  - PAL-GRF as Palestine’s realization of the **International Terrestrial Reference System (ITRS)**.
  - Establishes the digital framework for the National Spatial Data Infrastructure (NSDI).



PAL-GRF2023 Implementation

Eng Mohammad Maraheel

PAL-GRF2023: 1st Order Network Station Selection and Establishme

1.Station Selection by PLA Staff:

1. 10 candidate stations selected for the future CORS network.
2. Stations observed during PAL-GRF establishment works.

2.Selection Criteria:

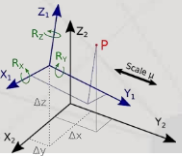
1. Focused on the west bank area. Future expansion to Gaza and all Palestinian lands.
2. Considered logistics, security, and other factors.

3.Station Monumentation:

1. All stations equipped with steel pillars featuring forced centering holes.
2. Materials supplied by the consultant; construction carried out by PLA staff.

Point criteria

- Secure
- Building older than 5 years
- Accessibility of power and Internet
- No signal disturbance
- Possible to be used as CORS in the future.
- Distances 50-70km (standard for CORS networks)



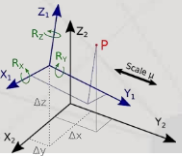
Observations

1.Observation Details:

1. Stations were observed **3-4 times** (refer to Table 7-1 and Table 7-2).
2. Each session lasted **at least 8 hours**.
3. Data intervals: **1/10/30 seconds**.
4. **30-second data interval** used (aligned with IGS standards).

2.Data Processing:

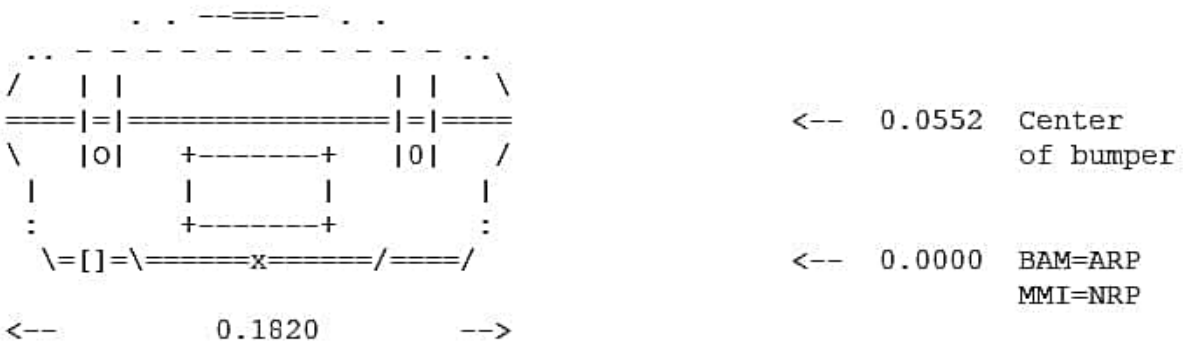
1. All GNSS observations were converted to **RINEX format** for further computations.



Equipment and Parameters: (NGS-standards calibrated)

TRMR8_GNSS
TRMR8_GNSS3
TRMR8-4

TRMR8S

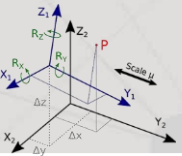


1st order Observations Table

- All stations are measured simultaneously
- Minimum time 8 hours
- Rinex format 3.02
- All files are pre-validated
- Any problem: a station is repeated with min both stations

Session	Date	Day of the year (doy)	GPS week_day
1	07.06.2023	158	2265_3
2	03.07.2023	184	2269_1
3	17.07.2023	198	2271_1
4	26.07.2023	207	2272_3

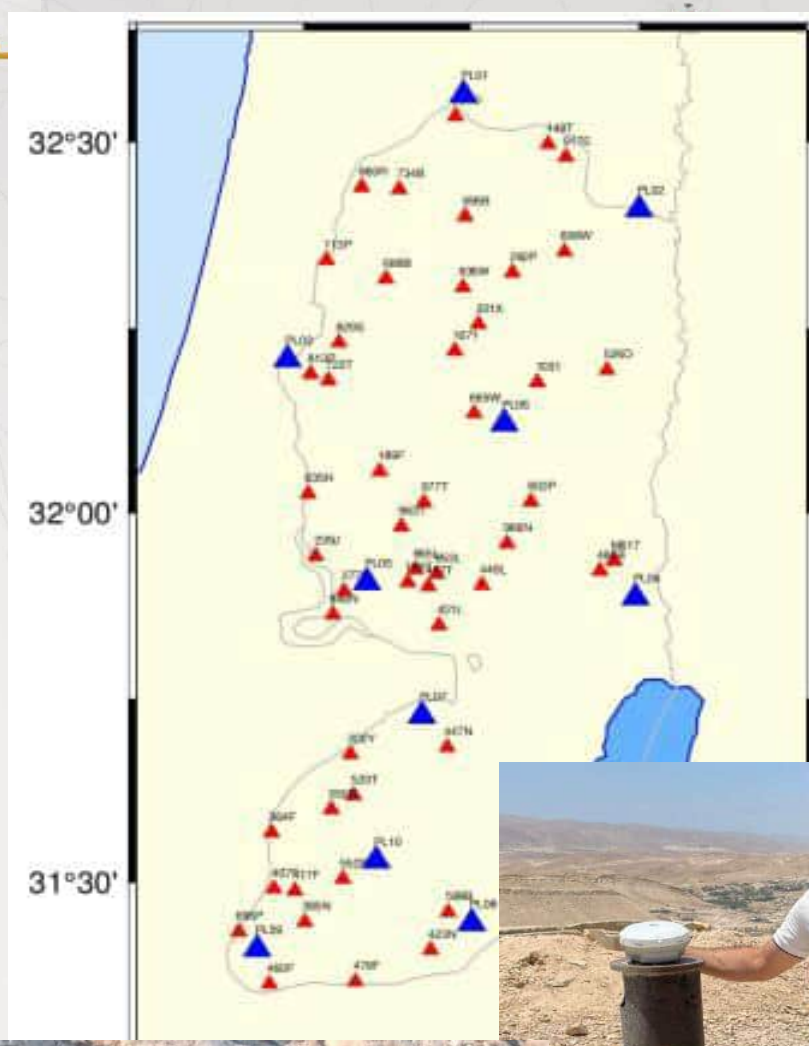
Date	doy	Stations Observed									
07.06.2023	158	PL01	PL02	PL03	PL04	PL05	PL06	PL07	PL08	PL09	PL10
03.07.2023	184	PL01	PL02	PL03	PL04	PL05	PL06	PL07	PL08	PL09	PL10
17.07.2023	198	PL01	PL02	PL03	PL04	PL05	PL06	PL07	PL08	PL09	PL10
26.07.2023	207				PL04	PL05		PL07		PL09	PL10



Used Global IGS & ITRF points

PAL-GRF2023 2nd Order Network (Pa1923 trig points)

- Conducted at **53 old triangulation points** with known Cassini-Soldner projection coordinates in PAL1923 datum.
- Simultaneous occupation of selected **PAL-GRF points**.
- GNSS measurements carried out on common points across the country.
- The distribution of common points ensures reliable determination of datum transformation parameters between PAL-GRF and PAL1923.



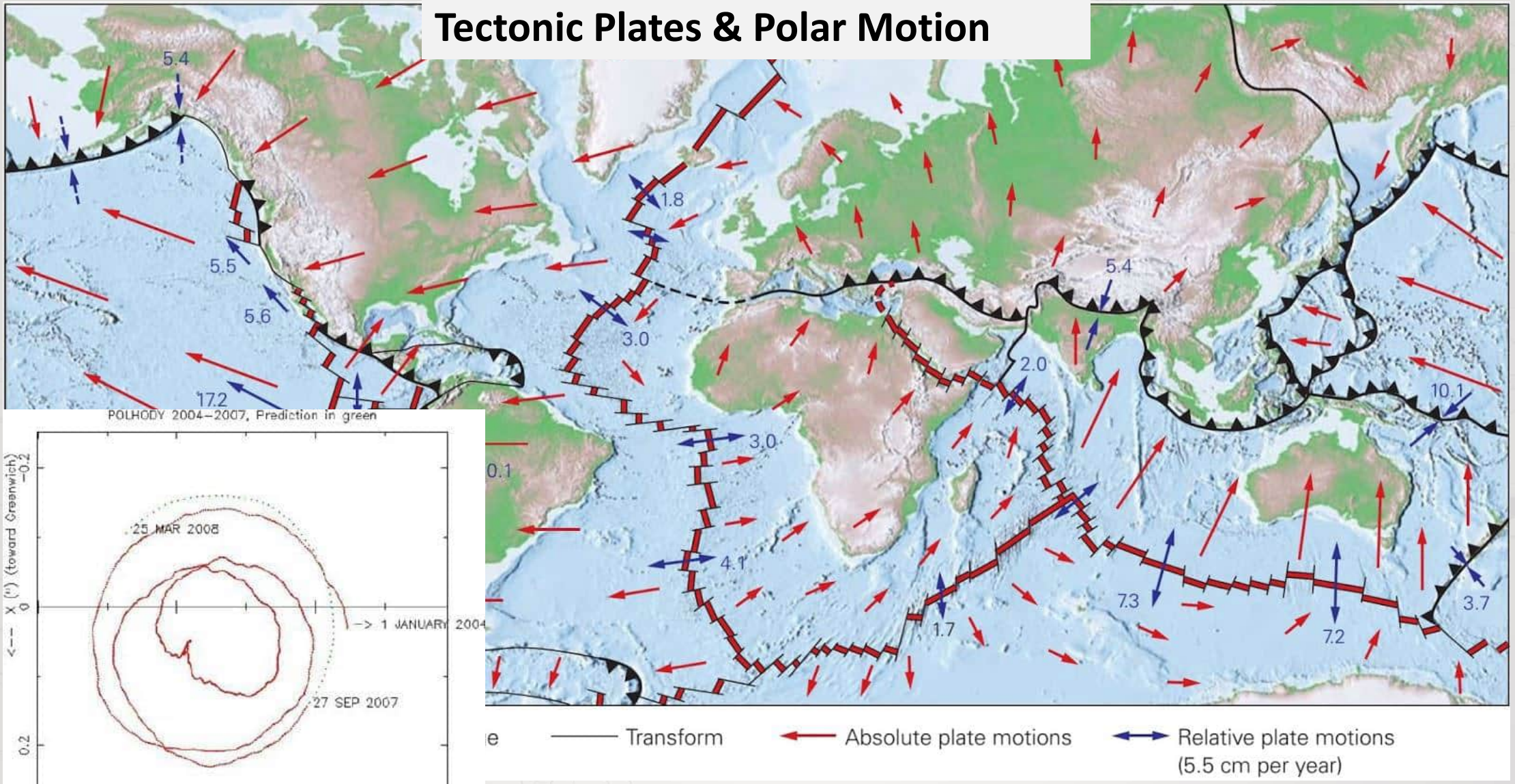
Observations Plan

Year	Mo	Day	Doy & Session#	Stations Measured										Group
2023	8	9	2210	447N	449L	608W	696P	813P	846N	M617	PL01	PL08		Group 1
2023	8	13	2250	1071	199T	302Y	417F	467T	486B	552B	722T	PL01	PL08	
2023	8	15	2270	113P	170L	321X	478F	520T	635H	636W	653L	PL01	PL08	
2023	8	16	2280	022Y	1031	423N	431L	526D	813S	977T	PL01	PL08		
2023	8	21	2330	447N	449L	608W	696P	813P	846N	M617	PL01	PL08		
2023	8	23	2350	1071	199T	302Y	417F	467T	486B	552B	722T	PL01	PL07	Group 2
2023	8	28	2400	113P	170L	321X	478F	520T	635H	636W	653L	PL01	PL07	
2023	8	29	2410	022Y	1031	423N	431L	599B	813S	977T	PL01	PL07		
2023	9	4	2470	189F	277B	364F	460F	599B	665L	829S	895B	966N	PL01	PL10	Group 3
2023	9	4	2471	189F	277B	364F	460F	599B	665L	829S	895B	966N			
2023	9	5	2480	148T	239J	385N	407F	550B	603P	665W	880R	963T	PL01	PL10	
2023	9	5	2481	148T	239J	385N	407F	550B	603P	665W	880R	963T			
2023	9	6	2490	292P	688B	734B	800D	917E	PL01	PL10					
2023	9	6	2491	292P	688B	734B	800D	917E							

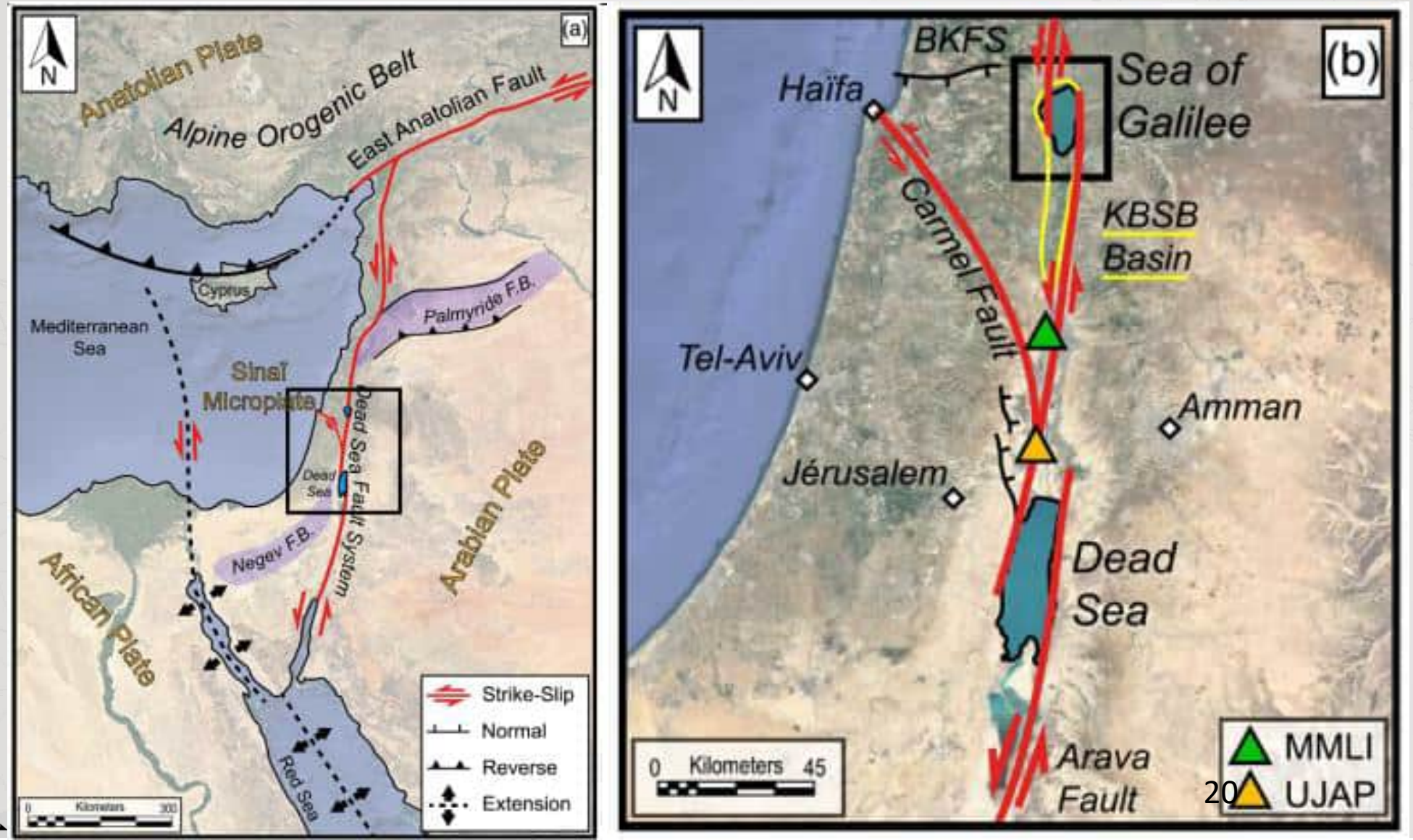
Calculations & Results

Dr. Ghadi Zakarneh

Tectonic Plates & Polar Motion

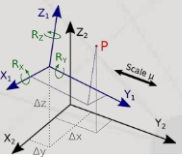


Local Earth Kinematics



Design of Pal-GRF2023

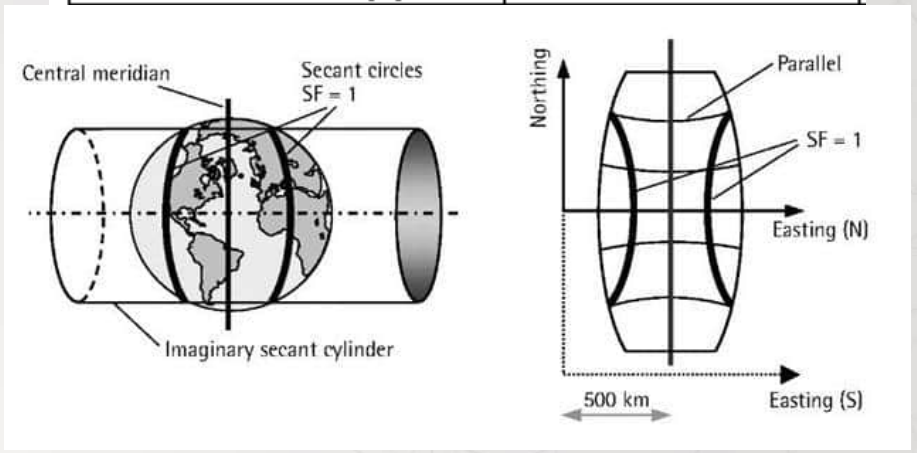
- Coordinate System: PAL-GRF2023_Grid
- Datum: Pal-GRF2023
- ITRF system: ITRF2020
- Reference Epoch: 2023.5
- Earth Shape: GRS80 (most globally accepted)
- Projection: Transverse Mecator (Globally accepted for longitudinal areas
- Implementation/Realization:
  - 10 1st order points: observed 8hours : ITRF coordinates and velocities
  - 50 second order points(original points from Pal1923Grid): observed 4hours.
  - The 2nd order points are to be user for connecting new system with old surveys.

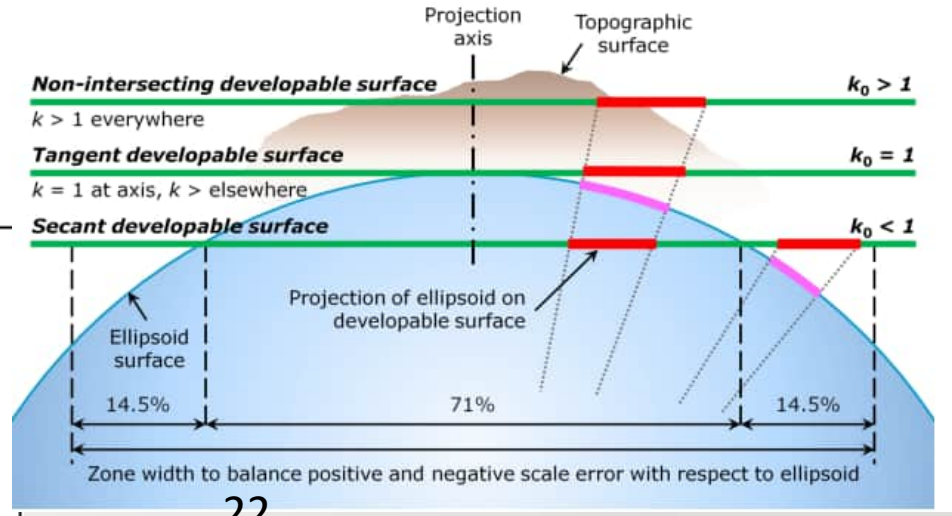


System Design Parameters

Parameter	Value
Ellipsoid	
Ellipsoid	GRS80
Semi-major axis (a)	6378137.00
Inverse flattening (f^{-1})	398.257 222 100 882
Semi-minor axis (b)	6356752.31414

Projection		
Projection Method	TM	
scale	1.000 003	• The projected coordinate will be nearly same of classically reduced field distances to the MSL • As Gaza is the farthest from the central meridian, the distortion are minimized by rising the projection surface near the topography (with small extension and topographic heights near MSL)
False Easting	220 000.00	• All easting coordinates in Palestine will positive • All Easting coordinates in Gaza and West Bank will have 6 digits : 1xxxxx or 2xxxxx
False Northing	500 000.00	• All Northing coordinates in Palestine will positive • All Coordinates in Gaza and west Bank will have 6 digits: 4xxxxx or 5xxxxx • In this case the classical mix between XY=EN or XY=NE can easily be recognized by numbers
Central Meridian	35.235000000 35° 14' 06.000000"	• Rounded values/without decimals of seconds and easy to written and inserted in different systems • The Centre of the projection will be located inside AQSA-Mosque in Jerusalem (the Capital City) • The central meridian passes through and near the largest possible area were infrastructures and cadastral surveys run in West Bank
Latitude of Origin	31.777 777 777 31° 46' 40.000000"	



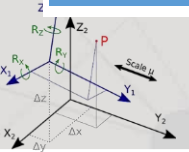


IGS-Stations

- Daily GNSS observation and Navigation files
- Station Coordinates to ITRF 2020 (t0: 2015)
- Station 3D velocities
- Extra: 3 ITRF stations (short base line for higher accuracy)

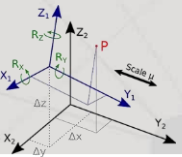
Station 3D kinematic Positions

NAME	X (m)	Y (m)	Z (m)	v_X (mm/y)	v_Y (mm/y)	v_Z (mm/y)	Tectonic Plate	
ADIS	4913652.7609	3945922.6696	995383.3331	-0.01922	0.01671	0.01820	AFRC	IGS
BSHM	4395951.1833	3080707.2289	3433498.2609	-0.02128	0.01243	0.01670	AFRC	IGS
DRAG	4432980.6621	3149432.0930	3322110.4410	-0.01986	0.01423	0.01873	AFRC	IGS
GRAZ	4194424.1240	1162702.4605	4647245.1930	-0.01695	0.01798	0.01039	EURA	IGS
ISTA	4208830.7260	2334850.0235	4171267.0890	-0.01773	0.01609	0.01002	EURA	IGS
NICO	4359415.5352	2874117.1781	3650777.9518	-0.01817	0.01118	0.01257	EURA	IGS
MAT1	4641951.2685	1393053.8493	4133281.0073	-0.01858	0.01903	0.01460	EURA	IGS
RAMO	4514721.8549	3133507.8433	3228024.6792	-0.02100	0.01411	0.01705	ARAB	IGS
SOFI	4319372.3900	1868687.5700	4292063.8000	-0.01698	0.01874	0.00827	EURA	IGS
ZECK	3451175.6956	3060336.4325	4391958.8536	-0.02210	0.01427	0.00890	EURA	IGS
ALON	4470258.1511	3084589.7721	3332952.7759	-0.02060	0.01326	0.01676	AFRC	ITRF2020
ELAT	4555028.6509	3180067.3419	3123164.4310	-0.02194	0.01602	0.01847	ARAB	ITRF2020
TELA	4443535.3843	3086140.8911	3366854.2050	-0.02068	0.01357	0.01749	ARAB	ITRF2020



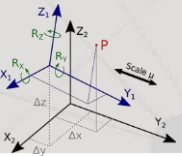
GNSS Data Processing at PAL-GRF Stations

- GNSS data collected at PAL-GRF stations post-processed using **Bernese GNSS Software**.
- Continuous GNSS data from **IGS stations** downloaded from IGS data centers.
- IGS analysis centers process data daily products:
  - Precise satellite orbits (GPS & GLONASS).
  - Station coordinates, Earth rotation parameters.
  - Satellite and receiver clock corrections.
  - Global ionosphere maps and troposphere parameters.
- Products support geodetic applications and ITRF maintenance.
- IGS final orbits available **13 days post-observation**.

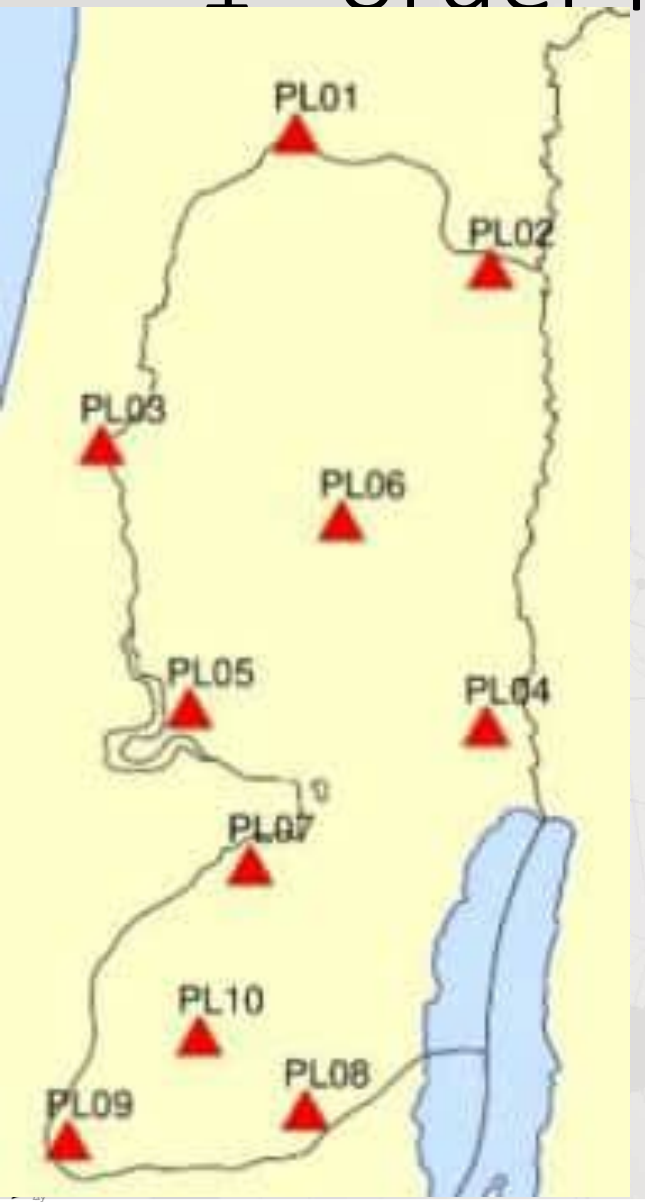


Adjustment of PAL-GRF GNSS Network

1. **PAL-GRF Campaign Overview:**
    1. 10 GNSS stations observed.+ RINEX data obtained from IGS and ITRF2020 stations.
2. **Data Processing:**
    1. Processed using **Bernese GNSS Software (BSW52)**., Utilized **CODE Analysis Center standard products**.
    2. Computed daily loosely constrained solutions (see Appendix-F).
3. **Combination of Solutions:**
    1. Daily loosely constrained solutions combined using **ADDNEQ2** program.
    2. Geodetic datum defined for the campaign.
    3. Loosely constrained campaign solution and definitive coordinates obtained in **ITRF2020** (02.07.2023, 2023.50).
4. **Minimally Constrained Solution:**
    1. Based on Reference IGS stations (No-Net-Translation).
    2. Coordinates reflect campaign-specific results and may vary slightly based on datum definition.
5. **Use of Loosely Constrained Solutions:**
    1. To combine epoch-wise solutions.
    2. To estimate station coordinates and associated velocity field.
    3. Allows re-definition of geodetic datum for epoch-wise solutions.



1st order Points (Least Squares)



Station	Longitude (deg)	Latitude (deg)	h (m)	VX (m)	VY (m)	VZ (m)	Velocity vector
PL01	35.22150	32.54270	140.8	-0.022	0.012	0.017	0.030
PL02	35.48364	32.38826	-43.08	-0.021	0.014	0.017	0.030
PL03	34.95930	32.18644	72.07	-0.022	0.012	0.016	0.030
PL04	35.47811	31.86476	-242.02	-0.022	0.013	0.018	0.032
PL05	35.07757	31.88534	426.37	-0.021	0.013	0.017	0.030
PL06	35.28258	32.10024	678.57	-0.021	0.014	0.017	0.031
PL07	35.15952	31.70481	882.5	-0.020	0.014	0.018	0.030
PL08	35.23418	31.42307	568.34	-0.020	0.014	0.018	0.030
PL09	34.91416	31.38784	620.08	-0.020	0.014	0.017	0.030
PL10	35.09131	31.50808	922.58	-0.020	0.014	0.018	0.030

STA.	Latitude			Std.dev	Longitude			Std.dev	Elip. H	Std.dev
	d	m	s	m	d	m	s	m	m	m
PL01	32	32	33.73654	0.0011	35	13	17.42874	0.0013	140.8009	0.0032
PL02	32	23	17.74073	0.0011	35	29	1.13067	0.0013	-43.0897	0.0031
PL03	32	11	11.21786	0.0011	34	57	33.48289	0.0013	72.0734	0.0032
PL04	31	51	53.14465	0.0010	35	28	41.21388	0.0013	-242.0254	0.0030
PL05	31	53	7.23937	0.0011	35	4	39.28594	0.0013	426.3733	0.0032
PL06	32	6	0.89644	0.0011	35	16	57.31225	0.0014	678.5779	0.0033
PL07	31	42	17.32799	0.0009	35	9	34.27758	0.0012	882.5043	0.0027
PL08	31	25	23.06869	0.0011	35	14	3.07276	0.0013	568.3492	0.0031
PL09	31	23	16.25514	0.0009	34	54	50.99479	0.0012	620.0848	0.0028
PL10	31	30	29.10888	0.0010	35	5	28.73693	0.0013	922.5812	0.0030

3D velocities

Station	Longitude (deg)	Latitude (deg)	h (m)	VX (m)	VY (m)	VZ (m)	Velocity vector
PL01	35.22150	32.54270	140.8	-0.022	0.012	0.017	0.030
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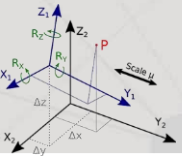
PL05	35.07757	31.88534	426.37	-0.021	0.013	0.017	0.030
PL06	35.28258	32.10024	678.57	-0.021	0.014	0.017	0.031
PL07	35.15952	31.70481	882.5	-0.020	0.014	0.018	0.030
PL08	35.23418	31.42307	568.34	-0.020	0.014	0.018	0.030
PL09	34.91416	31.38784	620.08	-0.020	0.014	0.017	0.030
PL10	35.09131	31.50808	922.58	-0.020			

$$X(t_i) = X_0 + V_0(t_i - t_0) + \sum_{k=1}^{n_o} O_k\, H_{o,k}(t_i) + \sum_{k=1}^{n_v} V_k\,(t_i - t_k)\, H_{v,k}(t_i) + \sum_{k=1}^{n_p} (A_k \cos(w_k\,(t_i - t_0)) + B_k \cos(w_k\,(t_i - t_0)))\, H_{p,k}(t_i)$$

Where;

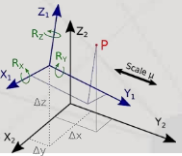
X_0 , station coordinate at an epoch t_0
V_0 , V_k , one or more station velocities
O_k , discontinuities
$H_{p,k}$, periodic functions with the predefined frequency w_k and the parameters (A_k and B_k)



PAL-GRF2023 2nd Order Network (Pa1923 trig points)

- Conducted at **53 old triangulation points** with known Cassini-Soldner projection coordinates in PAL1923 datum.
- Simultaneous occupation of selected **PAL-GRF points**.
- GNSS measurements carried out on common points across the country.
- The distribution of common points ensures reliable determination of datum transformation parameters between PAL-GRF and PAL1923.

Parameter	Criteria
Duration	PAL_GRF stations continuously Other stations 4 hours at least
Measurement number	2 times/station
Sampling rate	10 seconds
Minimum number of satellites to be observed	5
Antenna height measurement	At the beginning and end of the session
Precision of the antenna height measurement	mm



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2nd order – New vs Old

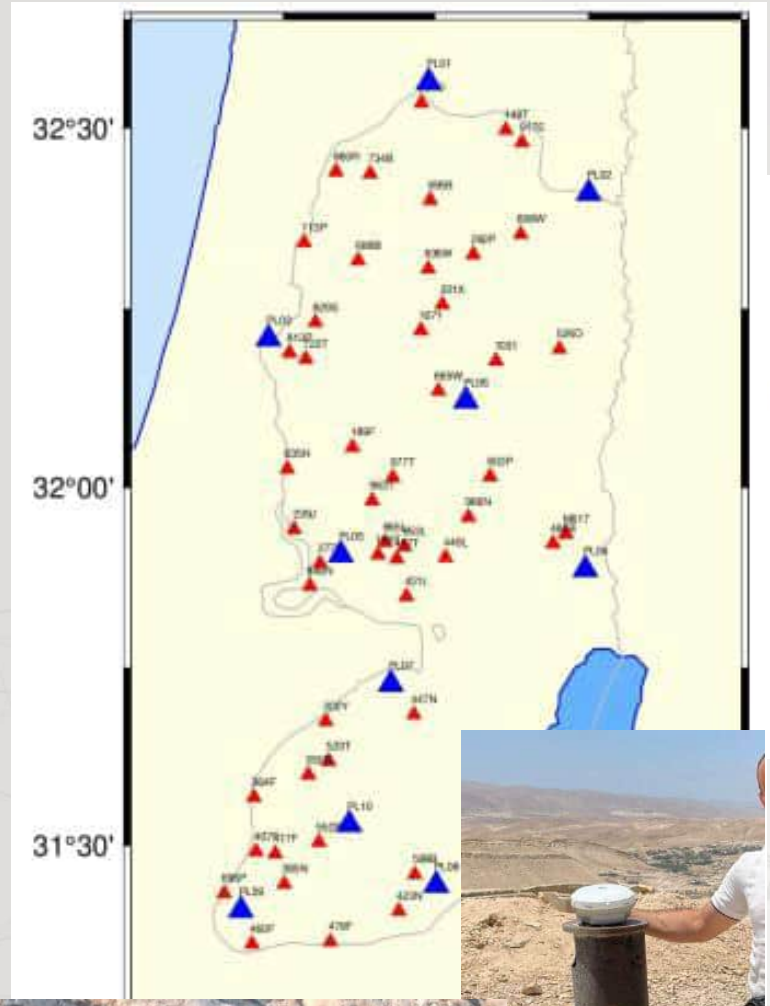


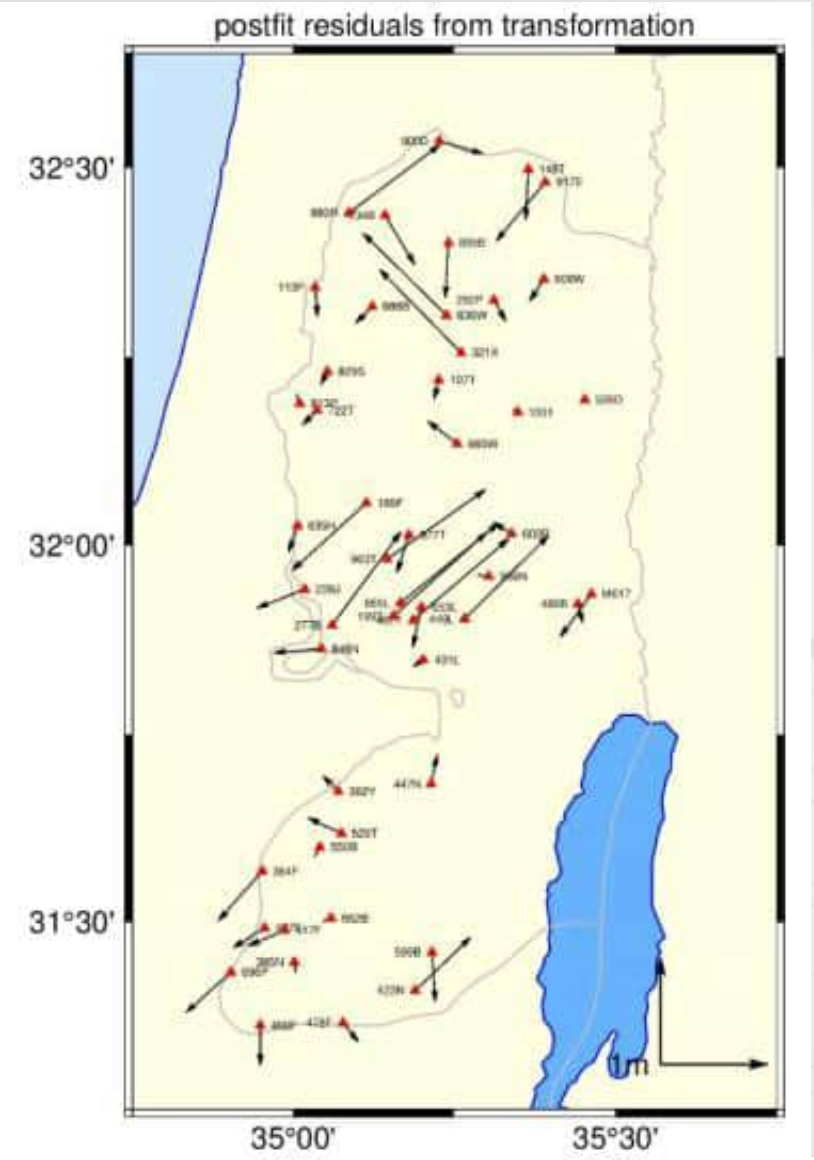
Table 11-4: The ITRF2020 coordinates of trig points used in the datum transformation

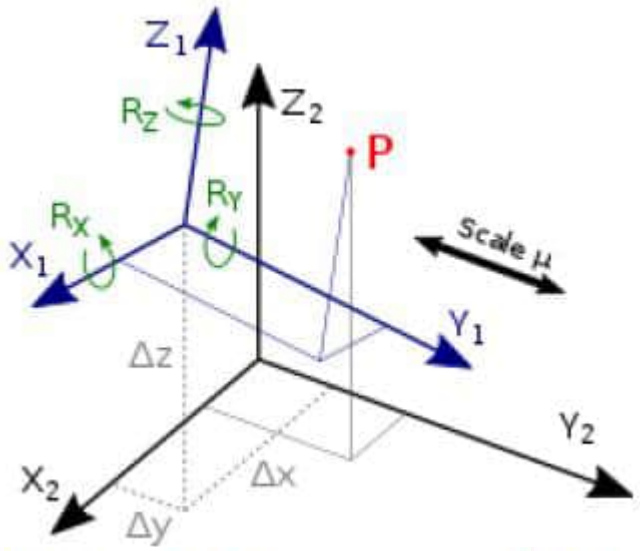
Station Name	Longitude	Latitude	Elipsoidal Height	X	Y	Z	Transversal Mercator	
	deg	deg	m	m	m	m	Easting (m)	Northing(m)
022Y	35.26221304	32.03197218	868.118	4419744.989	3124979.803	3363897.940	222570.56	528186.79
1031X	35.34820952	32.17660381	597.728	4407909.768	3126545.620	3377341.308	230677.00	544230.14
1071X	35.22567569	32.21942691	786.2689	4412649.300	3115744.026	3381460.585	219121.02	548973.24
113P	35.03409585	32.34169000	147.8046	4416671.429	3096505.184	3392582.933	201086.60	562548.95
148T	35.36437648	32.49756667	300.4518	4391295.916	3116624.202	3407257.002	232158.75	579824.45
170L	35.53958386	32.19211837	-196.9022	4396149.256	3140327.480	3378374.148	248721.06	545985.61
189F	35.11333211	32.05674030	498.4021	4426401.695	3112466.194	3366030.045	208510.27	530939.43
199T	35.15543330	31.90661626	783.8077	4431520.741	3120934.540	3352059.743	212473.86	514288.94
239J	35.01771626	31.94200758	281.5503	4436960.654	3108838.328	3355125.239	199455.18	518231.18

Table 11-5: The PAL1923 coordinates of trig points used in the datum transformation

Station Name	Longitude	Latitude	Elipsoidal Height	X	Y	Z	PAL1923 Grid (Cassini -Soldner)	
	deg	deg	m	m	m	m	Easting (m)	Northing(m)
022Y	35.26142030	32.03166780	868.118	4419984.275	3125057.264	3363637.969	174912.41	159863.78
1031X	35.34741096	32.17632199	597.728	4408148.421	3126622.550	3377082.986	183015.34	175910.64
1071X	35.22487694	32.21914138	786.2689	4412888.382	3115820.649	3381201.776	171457.89	180650.76
113P	35.03329121	32.34139955	147.8046	4416911.528	3096580.998	3392323.272	153419.40	194221.65
148T	35.36354881	32.49730720	300.4518	4391535.588	3116698.912	3406999.744	184487.06	211506.32
170L	35.53879155	32.19187790	-196.9022	4396385.340	3140404.307	3378119.659	201060.26	177674.34
189F	35.11255782	32.05644304	498.4021	4426639.877	3112544.276	3365770.664	160852.72	162614.21
199T	35.15465447	31.90630092	783.8077	4431759.715	3121012.720	3351799.152	164819.45	145963.22
239J	35.01695221	31.94169399	281.5503	4437198.989	3108913.203	3354864.699	151800.86	149902.83

Connecting Pal-GRF2023 to Pal1923





$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_2 = \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} (1+\delta) \quad \mathrm{R} \quad \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_1$$

3D Transformation Parameters (PAL-GRF to PAL1923)

$\Delta X = 114.5200 \pm 14.8542$ m

$\Delta Y = 79.3790 \pm 9.1074$ m

$\Delta Z = -281.6324 \pm 0.5174$ m

$R_X = -10.07015 \pm 0.51744$ arcsec

$R_Y = -8.45655 \pm 0.28998$ arcsec

$R_Z = -5.37202 \pm 0.74241$ arcsec

$\delta = 15.22329 \pm 1.23256$ ppm

$$R = R_Z R_Y R_X = \begin{bmatrix} cosR_Z & sinR_Z & 0 \\ -sinR_Z & cosR_Z & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} cosR_Y & 0 & -sinR_Z \\ 0 & 1 & 0 \\ sinR_Z & 0 & cosR_Y \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & cosR_X & sinR_Z \\ 0 & -sinR_Z & cosR_X \end{bmatrix}$$

Thank you

PAL-GRF2023 if website

- https://linktr.ee/PALGRF2023

PAL-GRF2023 Calculations Service

- pal-grf2023.github.io/Transform1/index.html