The New Palestinian Geodetic Reference Frame 2023 - Pal-GRF2023

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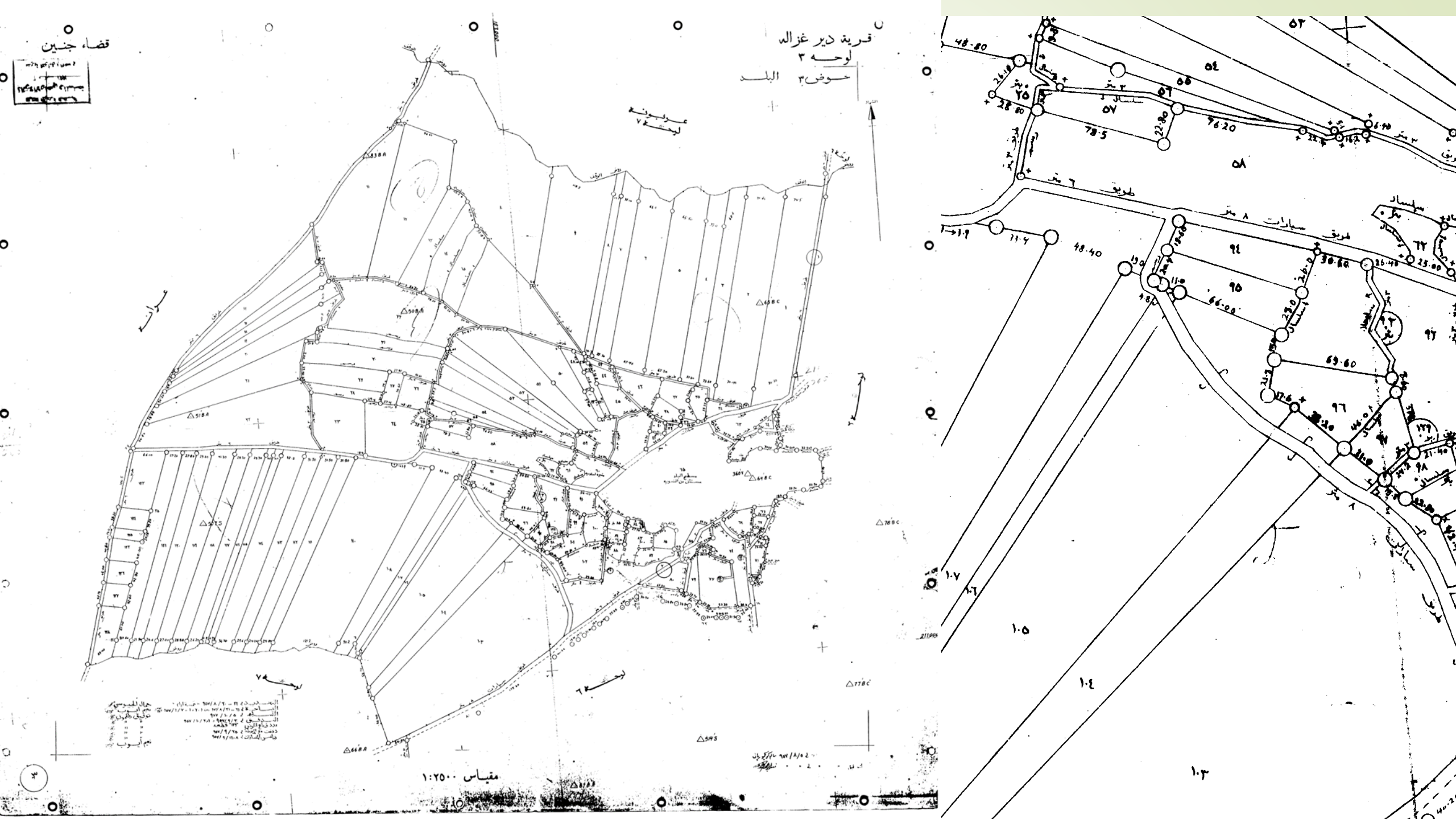
دولة فلسطين
سلطة الأراضي

Land Property Maps

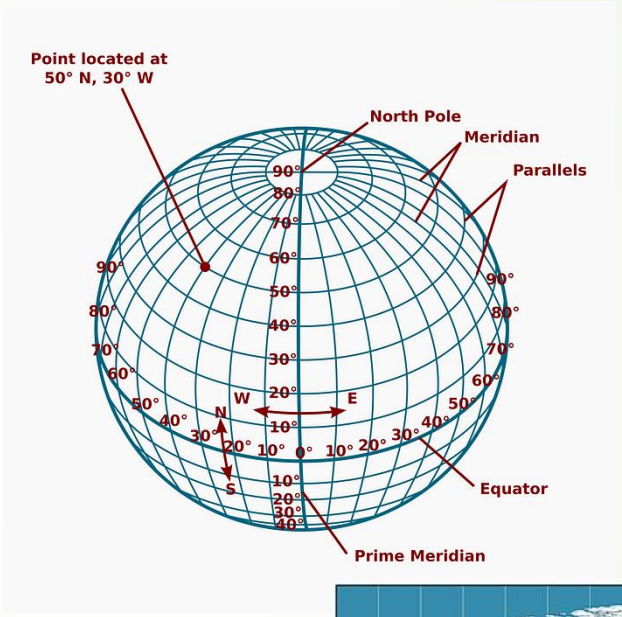
- Othman Era : Registration books (description of parcel position)
- British/Jordanian Era (Cadastral Mapping) : Village/Town→ Blocks → Parcels
- Hand drawings: scales 1:2500 1:1250 drawing accuracy ±0.5
- Chain & theodolite Surveying
- Required reference: continuous coordinates systems (2D): 2D Geodetic Network (Triangulation by theodolite) : Palestine 1923 system
- After Era (WestBank & Gaza): New registration for single parcels + Military orders.
- PNA / PNA (now): New registration for single parcels + Cadastral Mapping : using Modern Technology + high Level of measurement accuracy
- does the old Reference (Pal-1923) support the modern Technologies?

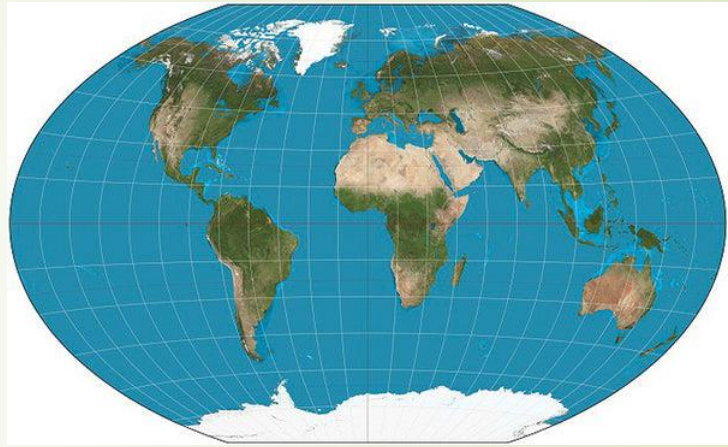

قضاء جنين
قرية دير غزاله
لوحه ٣
حوض ٣ البلد
مقياس ١:٢٥٠٠

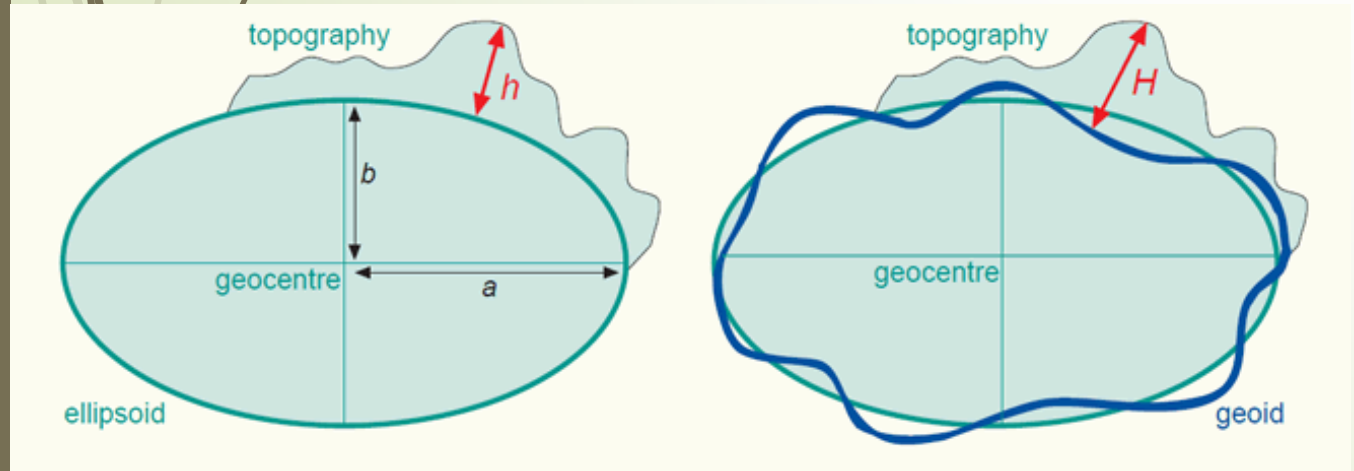
Common Questions in Land Surveying in Palestine

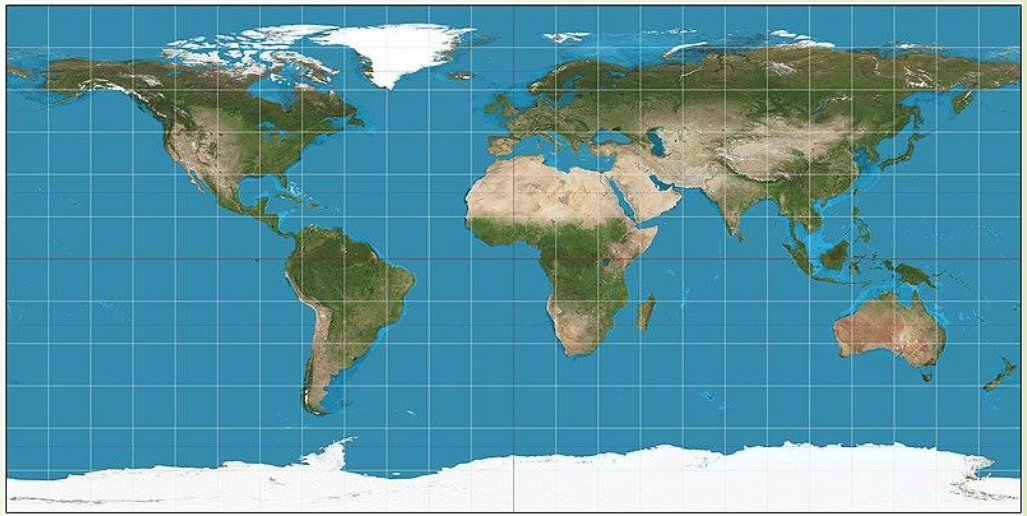
- Is the land parcel registered in new Palestinian **taswia** (clean ownership)
- Is it registered by Jordanian/British **taswia**
  - was is subjected to official/unofficial division
  - Are official land marks still available on the ground
  - Can you stackout the borders : how accurate + conflict with other neighboring surveys
- Unregistered
  - Can you prove the ownership of a land
  - How safe are you from hidden conflict
- How was a land surveyed: Tools & Techniques + what was the reference.
- Are you in a master plan area
- Are you in Oslo area A,B, or C.
- What ownership or planning rules is the parcel govern the parcel by the Jordanian-Palestinian or occupation civil administration
- Land Value/Price

Background (shape of the earth)

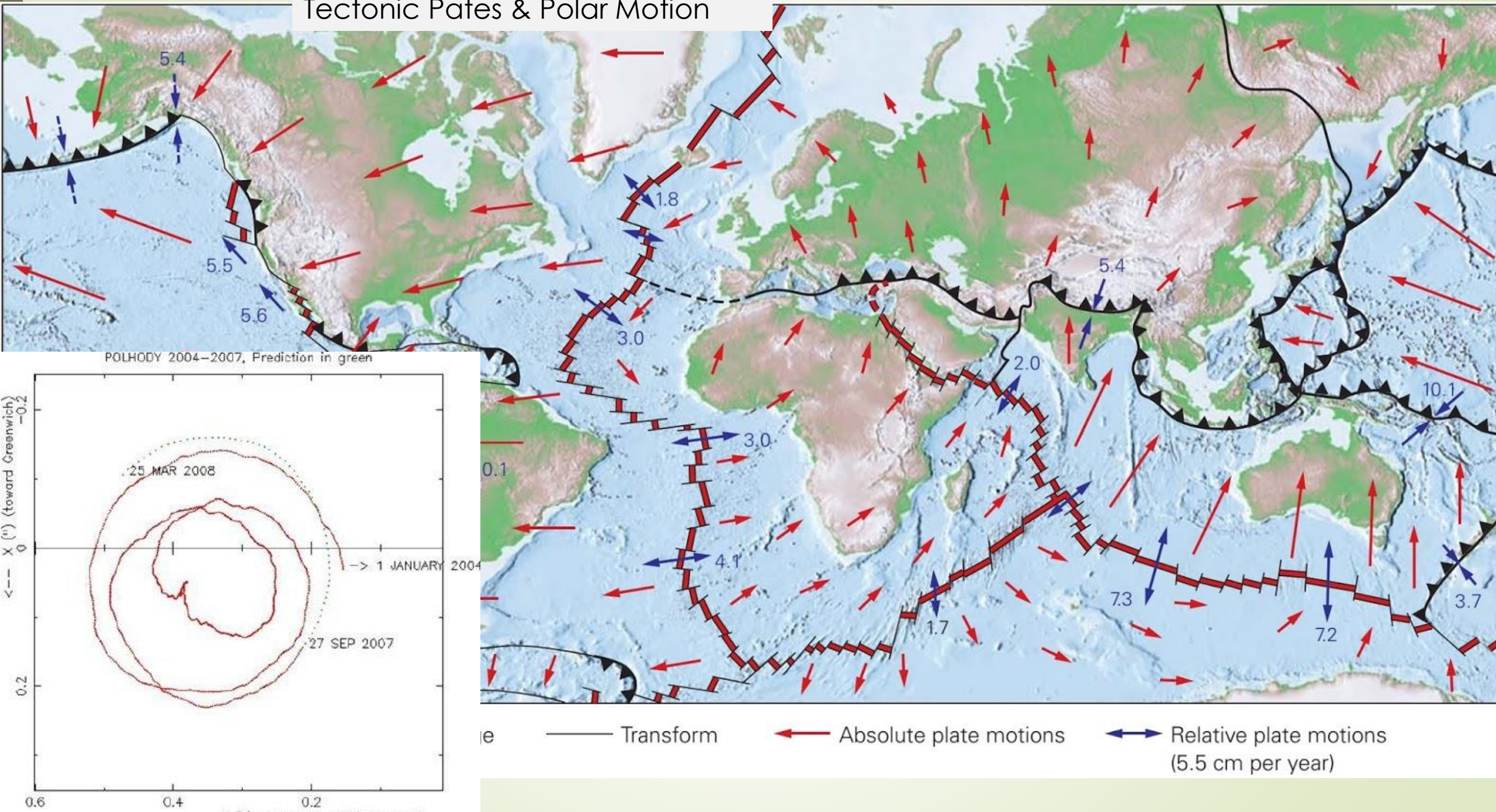








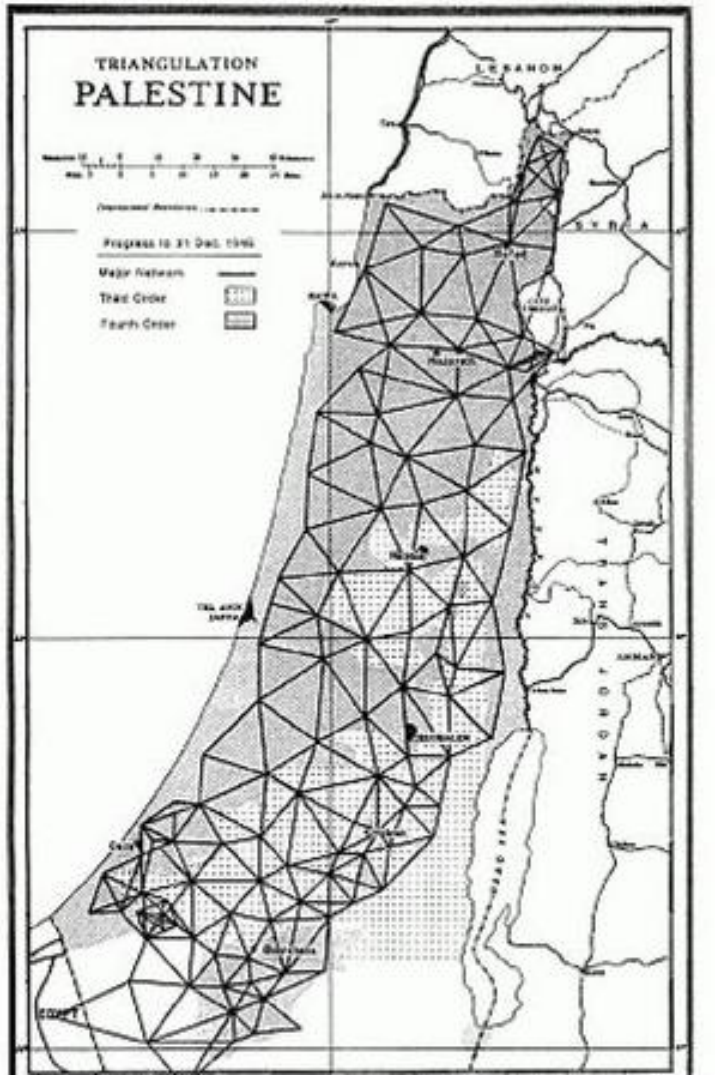
Tectonic Pates & Polar Motion



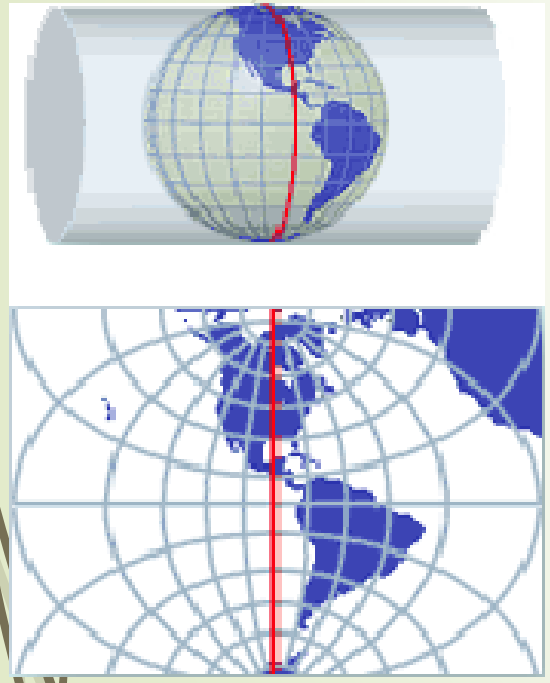
Classical Local Geodetic Networks Locally defined for local surveys

Palestinian Geodetic Network 1923-1947

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



Palestinian Projected coordinates 2D → 2D



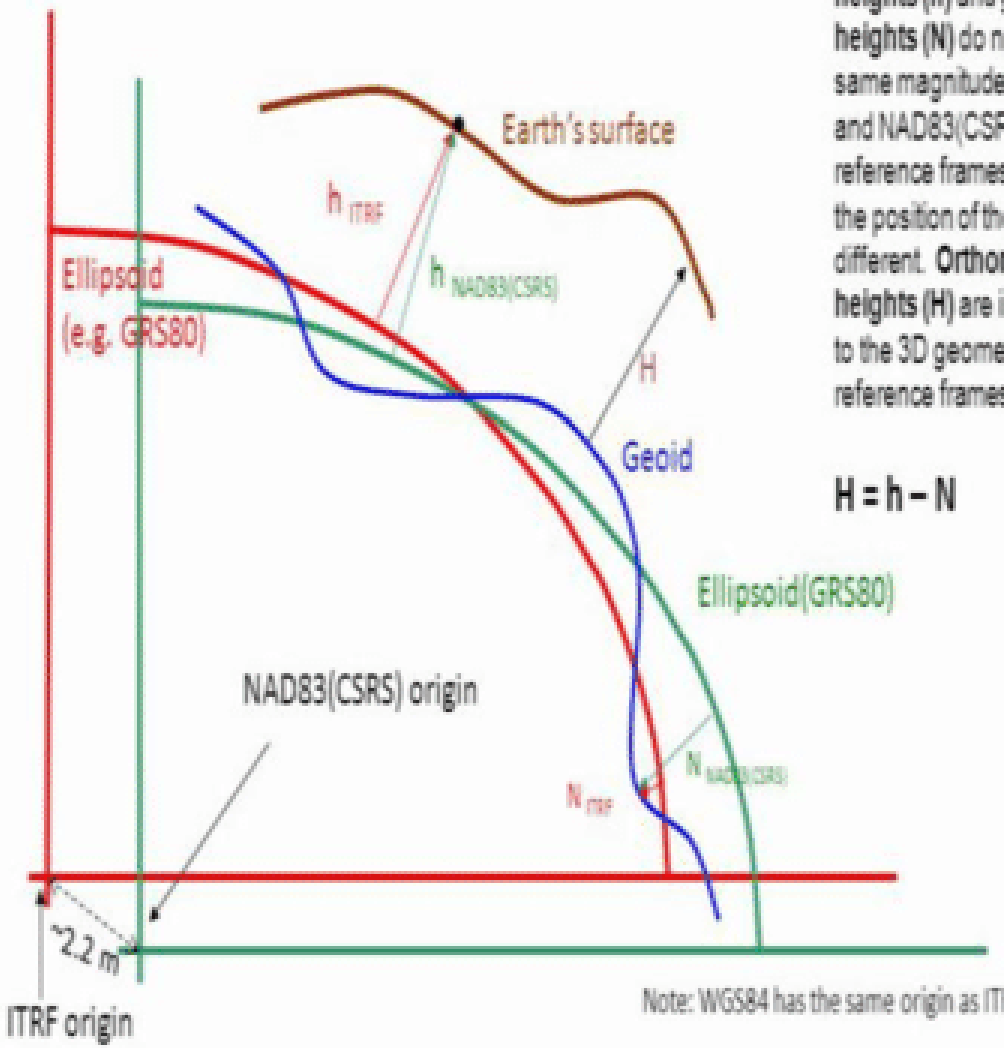
Parameter	Pal1923Grid
Ellipsoid	Clarck 1880
Semi-major axis	6378300.789m
Inverse flattening	293.4663155389802
Projection type	Transverse Cylinder
Projection Name	Cassini-Soldner
Latitude of origin	31.73409694444445°
Central meridian	35.21208055555556°
False easing	170251.555 m
False northing	126867.909 m
Scale	1
Datum	Palestine_1923
EPSG code	28191
Usage	Cadastral/Engineering

Global Coordinate Systems ?????

Satellites follow global systems : GPS / GNSS

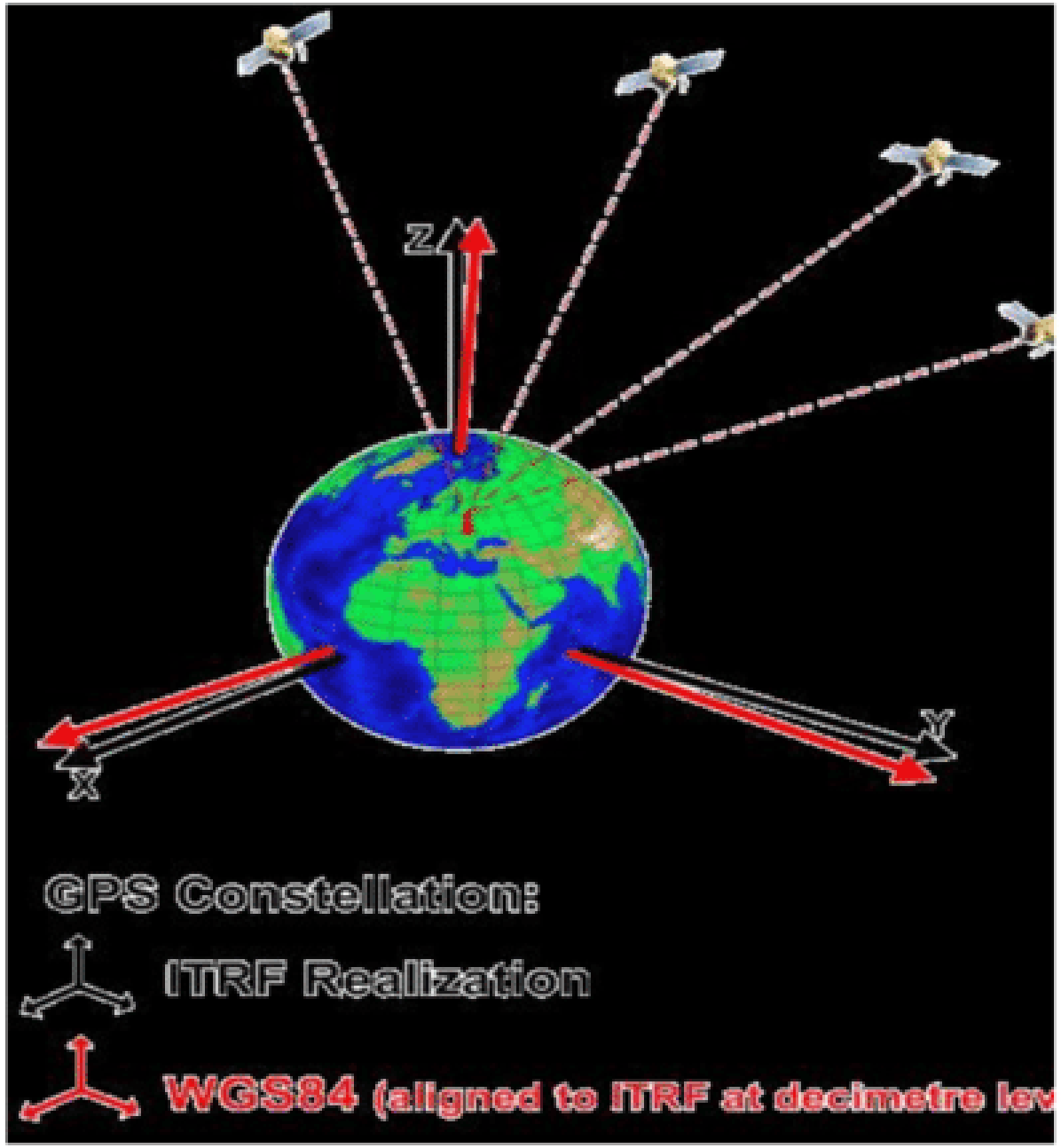
Regional / contental projects e.g. EURO

General concepts: Geometric reference frames (NAD83(CSRS), ITRF, WGS84)

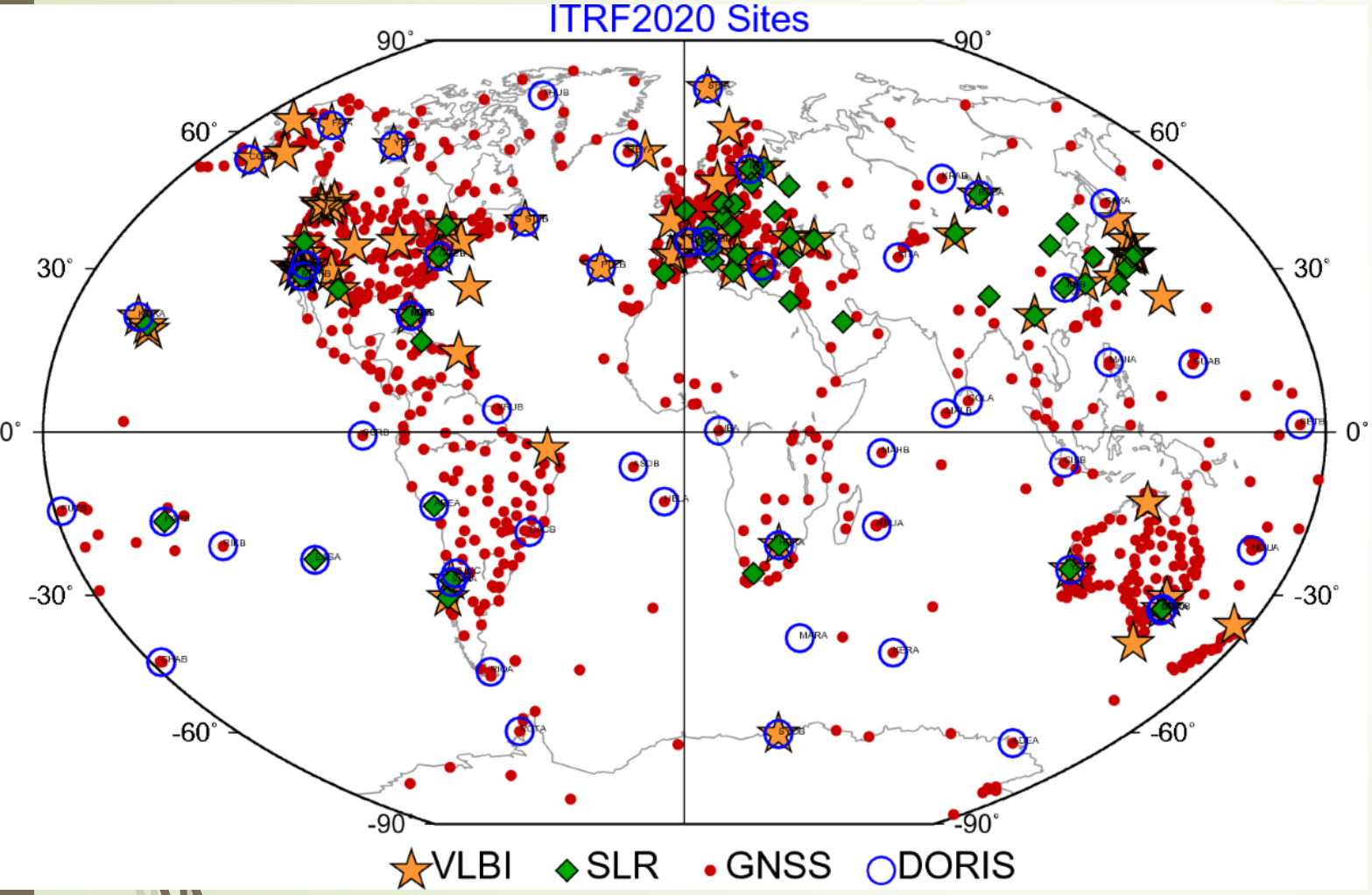


Geodetic (ellipsoidal) heights (h) and **geoid heights (N)** do not have the same magnitude in the ITRF and NAD83(CSRS) reference frames because the position of the origin is different. **Orthometric heights (H)** are independent to the 3D geometric reference frames.

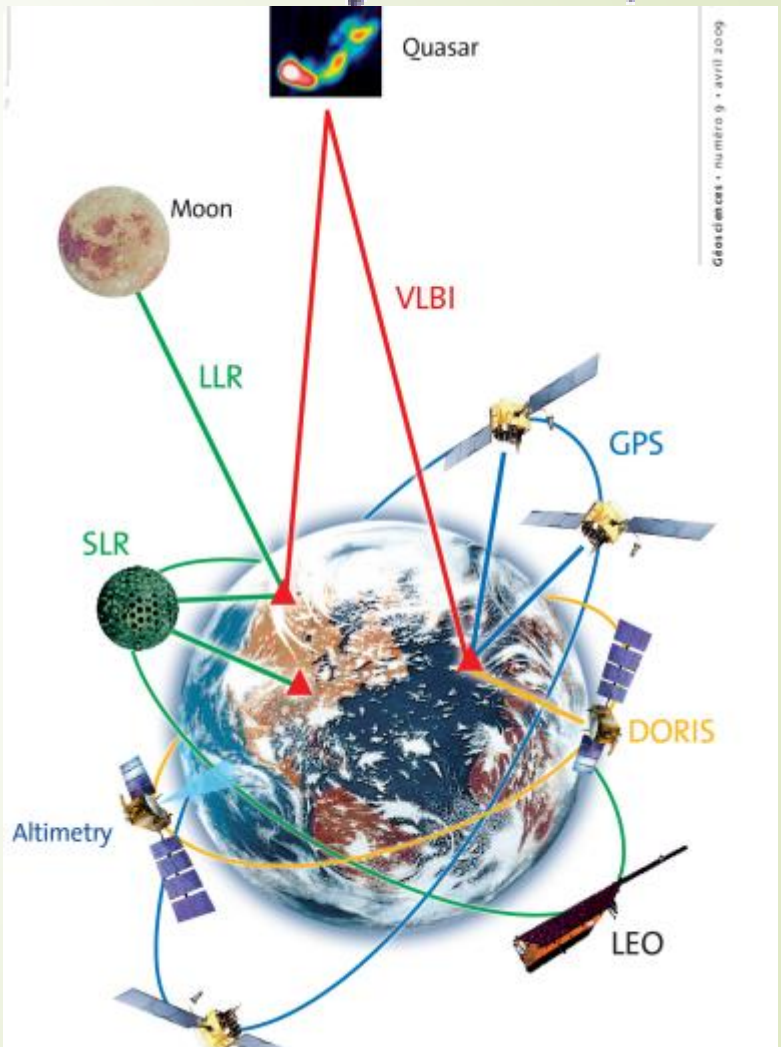
$$H = h - N$$



Common global system



International Terrestrial Reference Frame
I T R F



DATA AND PRODUCTS

File Access

IGS PRODUCTS

About
Terrestrial Frame
Tropospheric
Real Time Comparison
Precise Orbits and Clocks
Ionosphere
Differential Code Bias

ACCESS TO PRODUCTS

GPS Orbits + Satellites & Station Clocks
GLONASS Satellite Ephemerides
GNSS Broadcast Ephemeris
Geocentric Coordinates
Earth Rotation
Atmospheric Parameters

REAL-TIME SERVICE (RTS)

User Access
Formats
Contributors
Products
Monitoring

MULTI-GNSS (MGEX)

ANALYSIS CENTER COORDINATION

Analysis Centers
ACC Newsfeed
ReProcessing
ACC Resources

GPS-ONLY

Ultra-Rapid
Final
PPP
Rapid
Broadcast

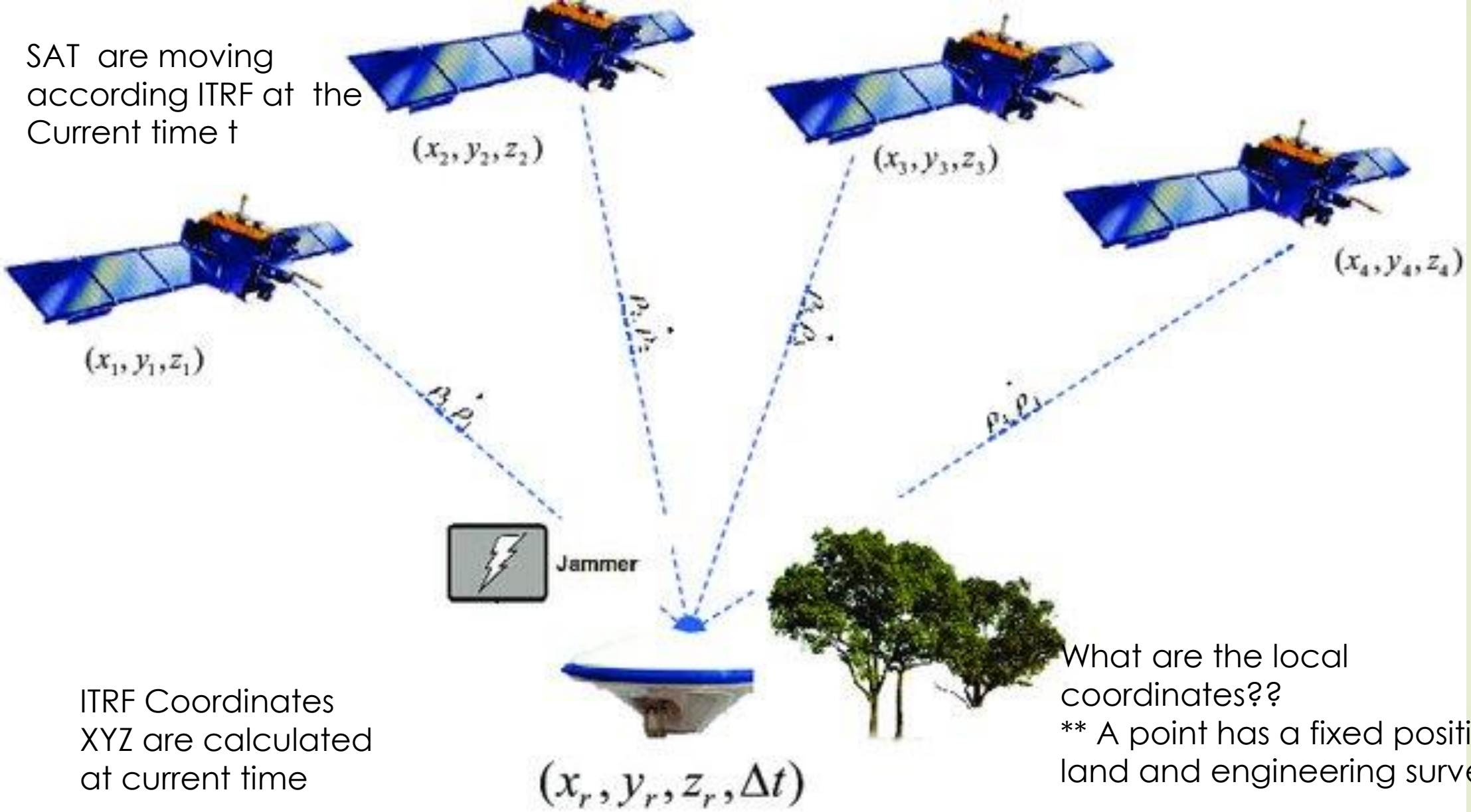
GLONASS-ONLY

Ultra-Rapid

Transformation parameters from ITRF2020 to past ITRFs.

SOLUTION	Tx	Ty	Tz	D	Rx	Ry	Rz	EPOCH
UNITS---------->	mm	mm	mm	ppb	.001"	.001"	.001"	
	.	.	.	.	.	.	.	
RATES	Tx	Ty	Tz	D	Rx	Ry	Rz	
UNITS---------->	mm/y	mm/y	mm/y	ppb/y	.001"/y	.001"/y	.001"/y	
ITRF2014	-1.4	-0.9	1.4	-0.42	0.00	0.00	0.00	2015.0
rates	0.0	-0.1	0.2	0.00	0.00	0.00	0.00	
ITRF2008	0.2	1.0	3.3	-0.29	0.00	0.00	0.00	2015.0
rates	0.0	-0.1	0.1	0.03	0.00	0.00	0.00	
ITRF2005	2.7	0.1	-1.4	0.65	0.00	0.00	0.00	2015.0
rates	0.3	-0.1	0.1	0.03	0.00	0.00	0.00	
ITRF2000	-0.2	0.8	-34.2	2.25	0.00	0.00	0.00	2015.0
rates	0.1	0.0	-1.7	0.11	0.00	0.00	0.00	
ITRF97	6.5	-3.9	-77.9	3.98	0.00	0.00	0.36	2015.0
rates	0.1	-0.6	-3.1	0.12	0.00	0.00	0.02	
ITRF96	6.5	-3.9	-77.9	3.98	0.00	0.00	0.36	2015.0
rates	0.1	-0.6	-3.1	0.12	0.00	0.00	0.02	
ITRF94	6.5	-3.9	-77.9	3.98	0.00	0.00	0.36	2015.0
rates	0.1	-0.6	-3.1	0.12	0.00	0.00	0.02	
ITRF93	-65.8	1.9	-71.3	4.47	-3.36	-4.33	0.75	2015.0
rates	-2.8	-0.2	-2.3	0.12	-0.11	-0.19	0.07	
ITRF92	14.5	-1.9	-85.9	3.27	0.00	0.00	0.36	2015.0
rates	0.1	-0.6	-3.1	0.12	0.00	0.00	0.02	
ITRF91	26.5	12.1	-91.9	4.67	0.00	0.00	0.36	2015.0
rates	0.1	-0.6	-3.1	0.12	0.00	0.00	0.02	
ITRF90	24.5	8.1	-107.9	4.97	0.00	0.00	0.36	2015.0
rates	0.1	-0.6	-3.1	0.12	0.00	0.00	0.02	
ITRF89	29.5	32.1	-145.9	8.37	0.00	0.00	0.36	2015.0
rates	0.1	-0.6	-3.1	0.12	0.00	0.00	0.02	
ITRF88	24.5	-3.9	-169.9	11.47	0.10	0.00	0.36	2015.0
rates	0.1	-0.6	-3.1	0.12	0.00	0.00	0.02	

SAT are moving according ITRF at the Current time t

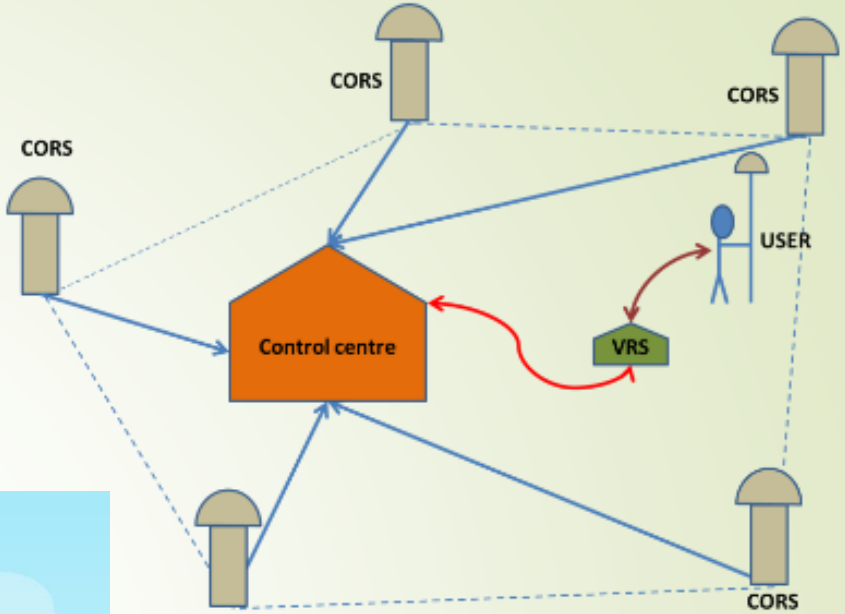


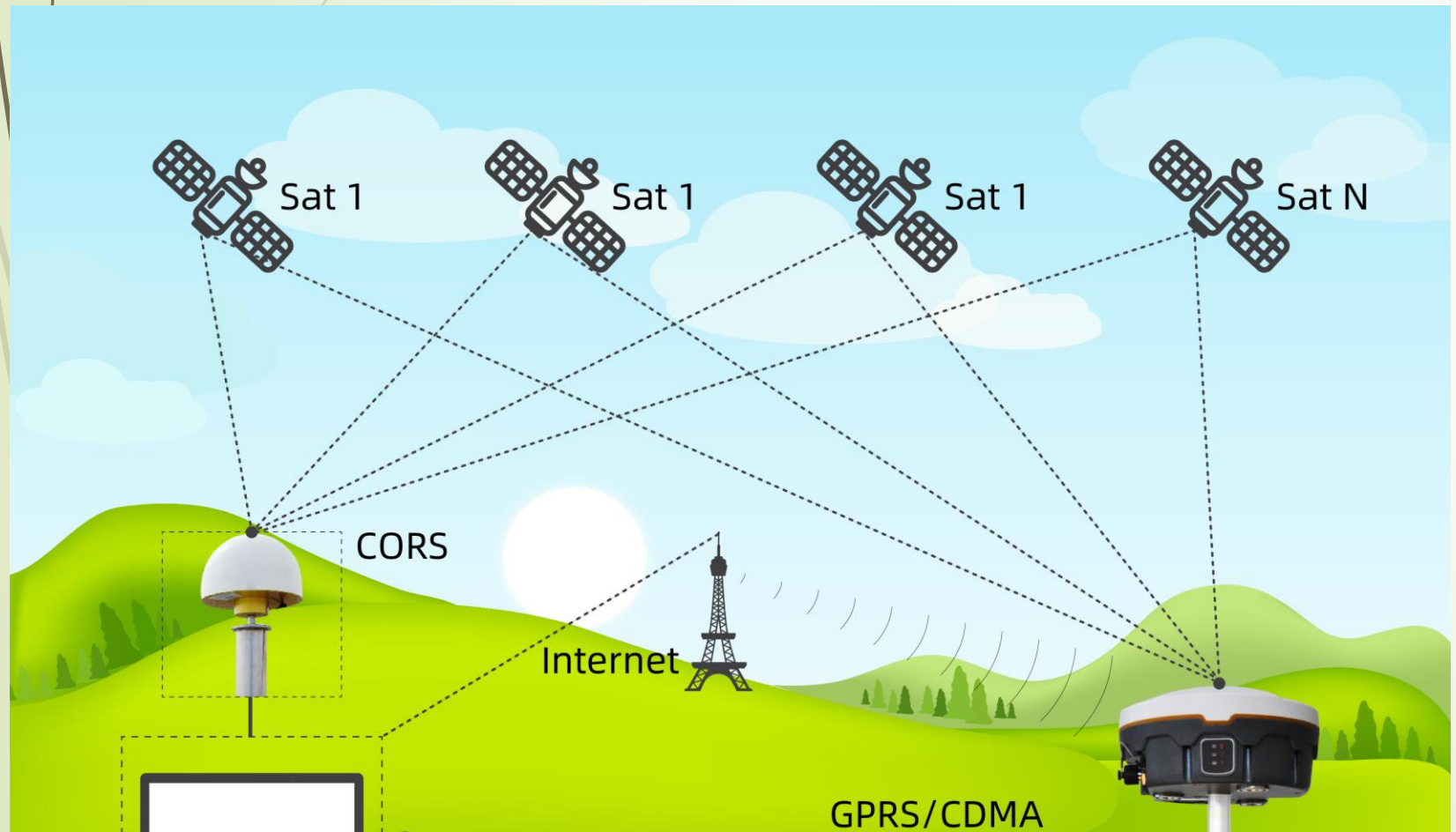
ITRF Coordinates XYZ are calculated at current time

What are the local coordinates??
** A point has a fixed position in land and engineering surveys

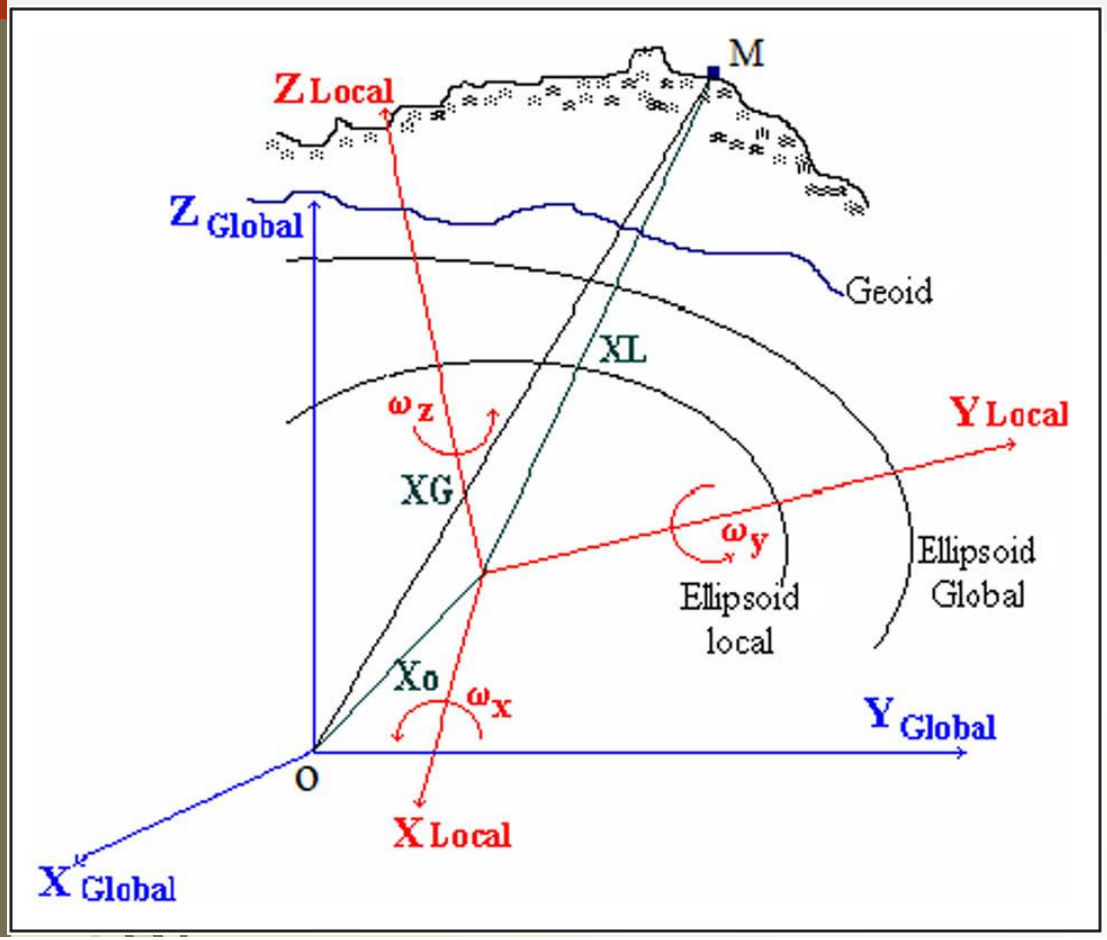
epoch t_0	Position (m)			Velocity (m/y)		
	X	Y	Z	V_X	V_Y	V_Z
001/2015	4432980.456 ± 0.001	3149432.232 ± 0.001	3322110.646 ± 0.001	-0.0199 ± 0.0001	0.0142 ± 0.0001	0.0187 ± 0.0001

Network of local coordinates

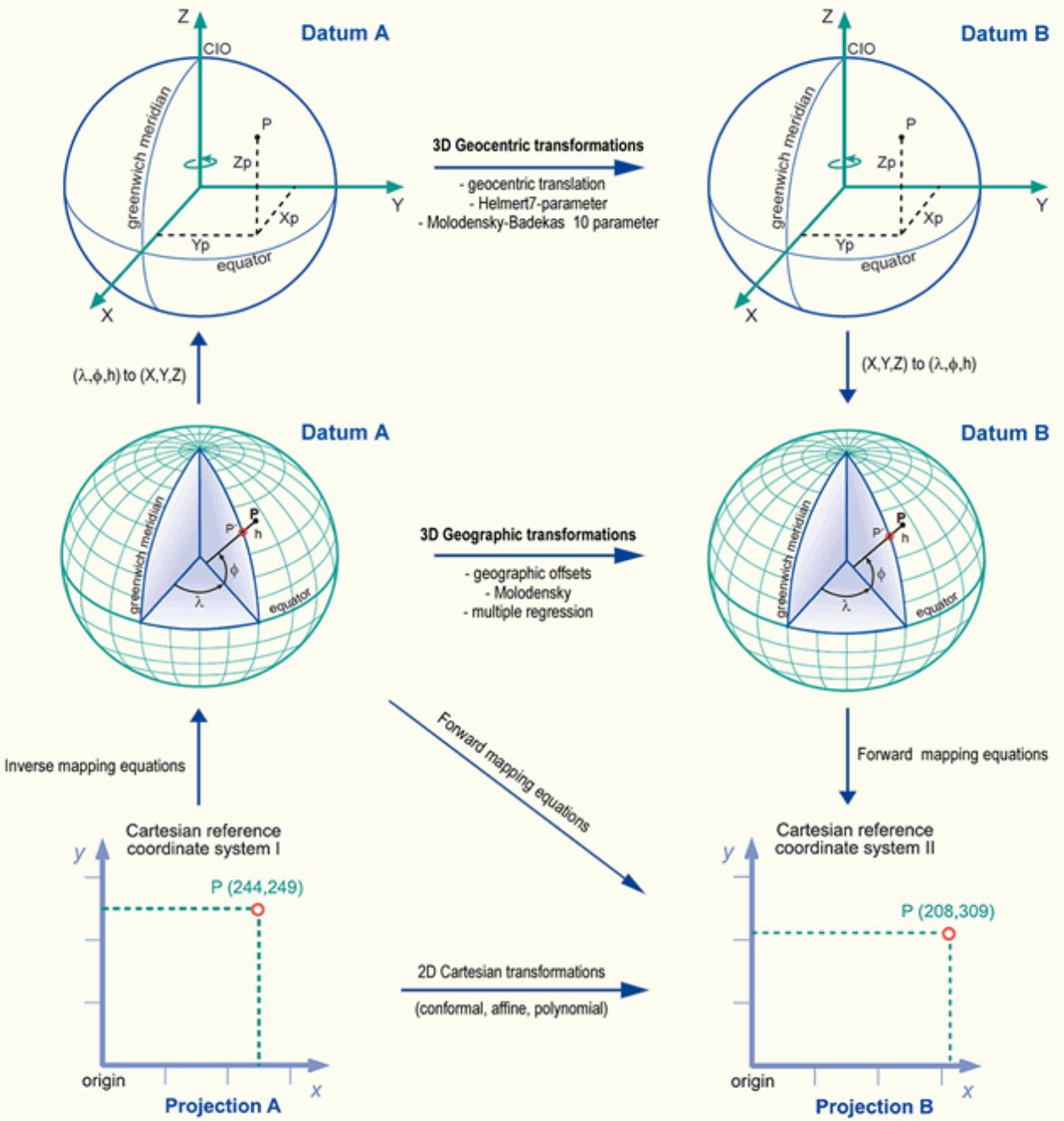




Connection global to local systems - Datum Transformations



$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{Local} = (1+s) \begin{bmatrix} 1 & r_z & -r_y \\ -r_z & 1 & r_x \\ r_y & -r_x & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS84} + \begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix}$$



No governmental **specifications** for surveying with modern methods

Table 1. Projected coordinate systems in Palestine (Epsg 2019)

Parameter	Pal1923Grid	Pal1923Belt	New Pal-TM[1]
Ellipsoid	Clarck 1880	Clarck 1880	GRS 80
Semi-major axis	6378300.789m	6378300.789m	6378137.00m
Inverse flattening	293.4663155389802	293.4663155389802	298.257222100882
Projection type	Transverse Cylinder	Transverse Cylinder	Transverse Cylinder
Projection Name	Cassini-Soldner	Transverse Mercator	Transverse Mercator
Latitude of origin	31.734096944444445°	31.734096944444445°	31.73439361°
Central meridian	35.212080555555556°	35.212080555555556°	35.20451694°
False easing	170251.555 m	170251.555 m	169529.584 m
False northing	126867.909 m	126867.909 m	126907.39 m
Scale	1	1	1.0000067
Datum	Palestine_1923	Palestine_1923	ITRF00/2004.75
EPSG code	28191	28192	--
Usage	Cadastral/Engineering	Cartography/Mapping	Cadastral/Engineering

The transformed three dimensional coordinates projected coordinates are assumed to be equal to Pal1913Grid coordinates, although the different map projection and reference ellipsoid are integrated with a different datum.

Transformations between Local and Global systems in Palestine

Table 2. List of the most common datum transformation parameters used in Palestine (ESRI, ArcGIS 10.7.1 and ArcGIS Pro 2.4 Geographic and Vertical Transformation Tables 2019)

Parameter	Method				
	A	B	C	D	E
Source	Trimble TBC	Esri	Esri/QGIS	GNSS-provider A	GNSS-provider B
(ppm)	0	0	0	8.8471	5.4248
(sec)	0	0	-8.001	-11.1499	-0.33009
(sec)	0	0	-4.42	-8.56249	-1.85269
(sec)	0	0	-11.821	-5.04769	1.66969
(m)	230	219.247	275.722	121.451	-24.0024
(m)	71	73.802	-94.782	114.142	-17.1032
(m)	-273	-269.529	-340.894	-284.684	-17.8444
Ellipsoid	Clarck1880	Clarck1880	Clarck1880	Clarck1880	GRS80
Related Projected coordinates	Pal1923grid (Cassini)	Pal1923grid (Cassini)	Pal1923grid (Cassini)	Pal1923grid (Cassini)	New Pal-TM

Validating the Old system in Palestine

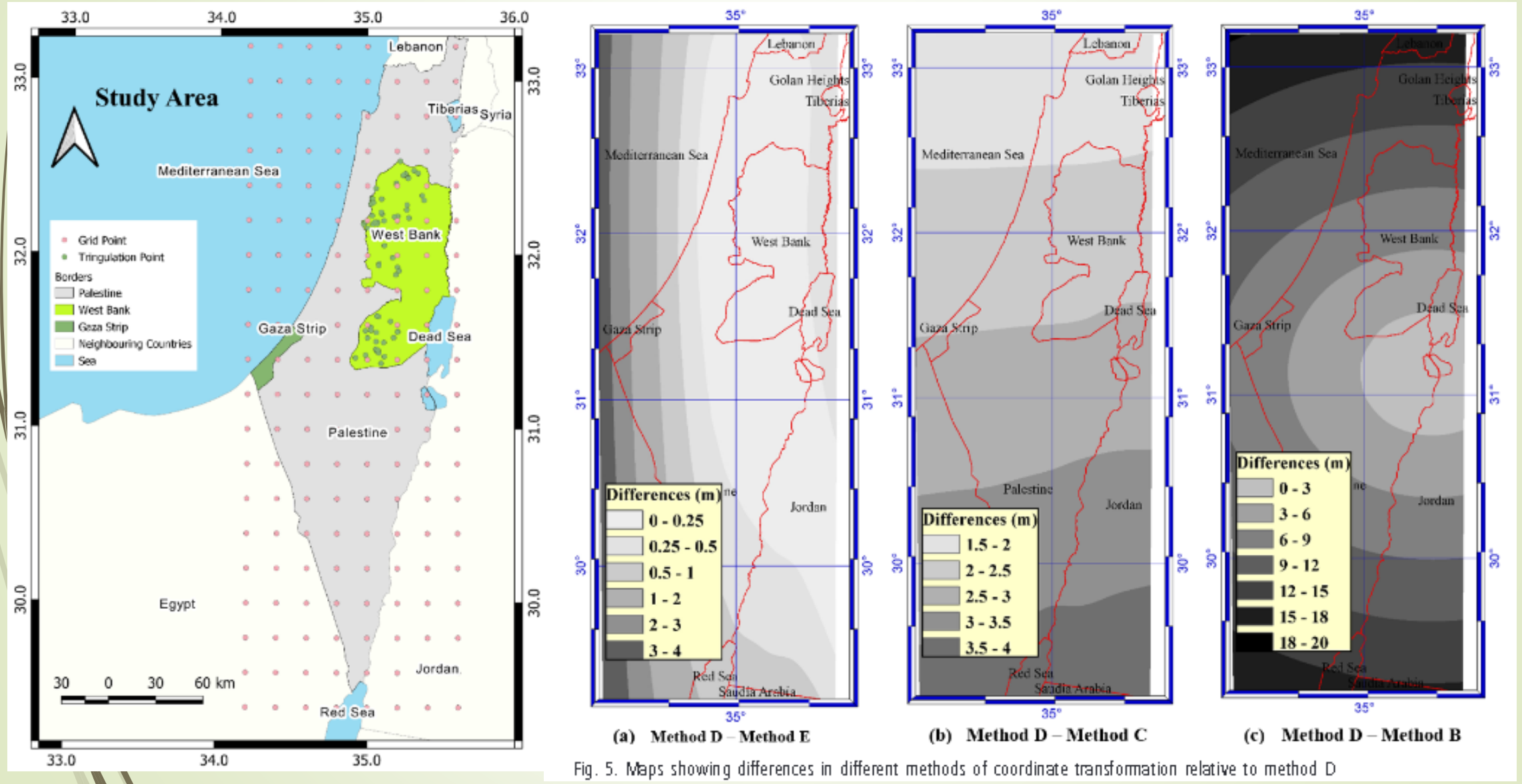


Fig. 5. Maps showing differences in different methods of coordinate transformation relative to method D

Why Pal-GRF2023

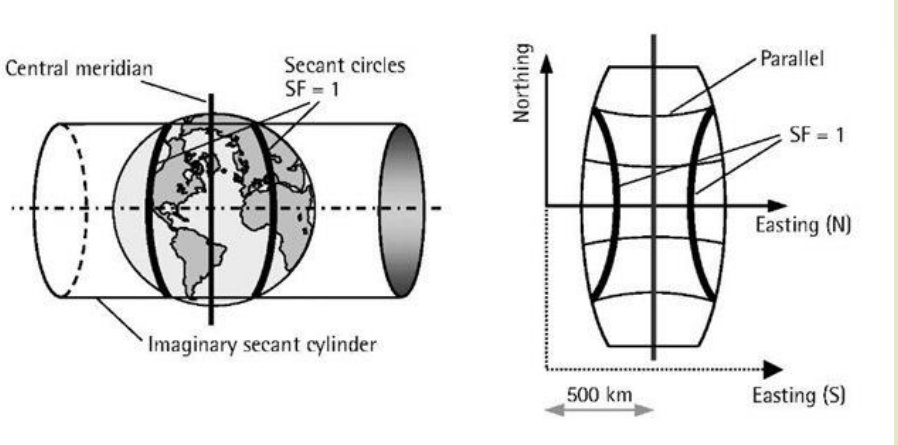
- An Intermediate system between : Kinematic positioning (Satellite Orbits , tectonic Plates) and static positioning (Land/engineering surveying)
- High level of accuracy (mm-cm): compatible with GPS/GNSS Positioning, Drone Photogrammetry, and Laser Scanning.
- A unified official system to be used for 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.

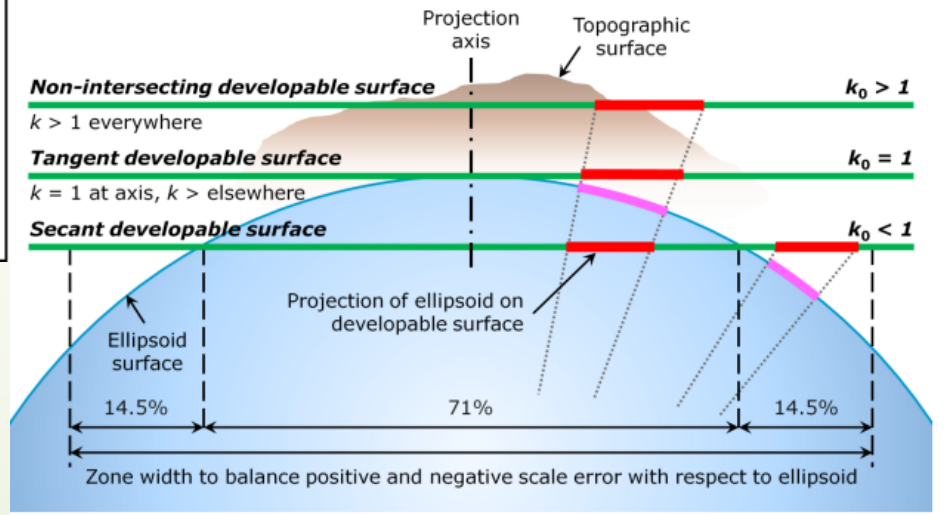
Design of Pal-GRF2023

- 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.

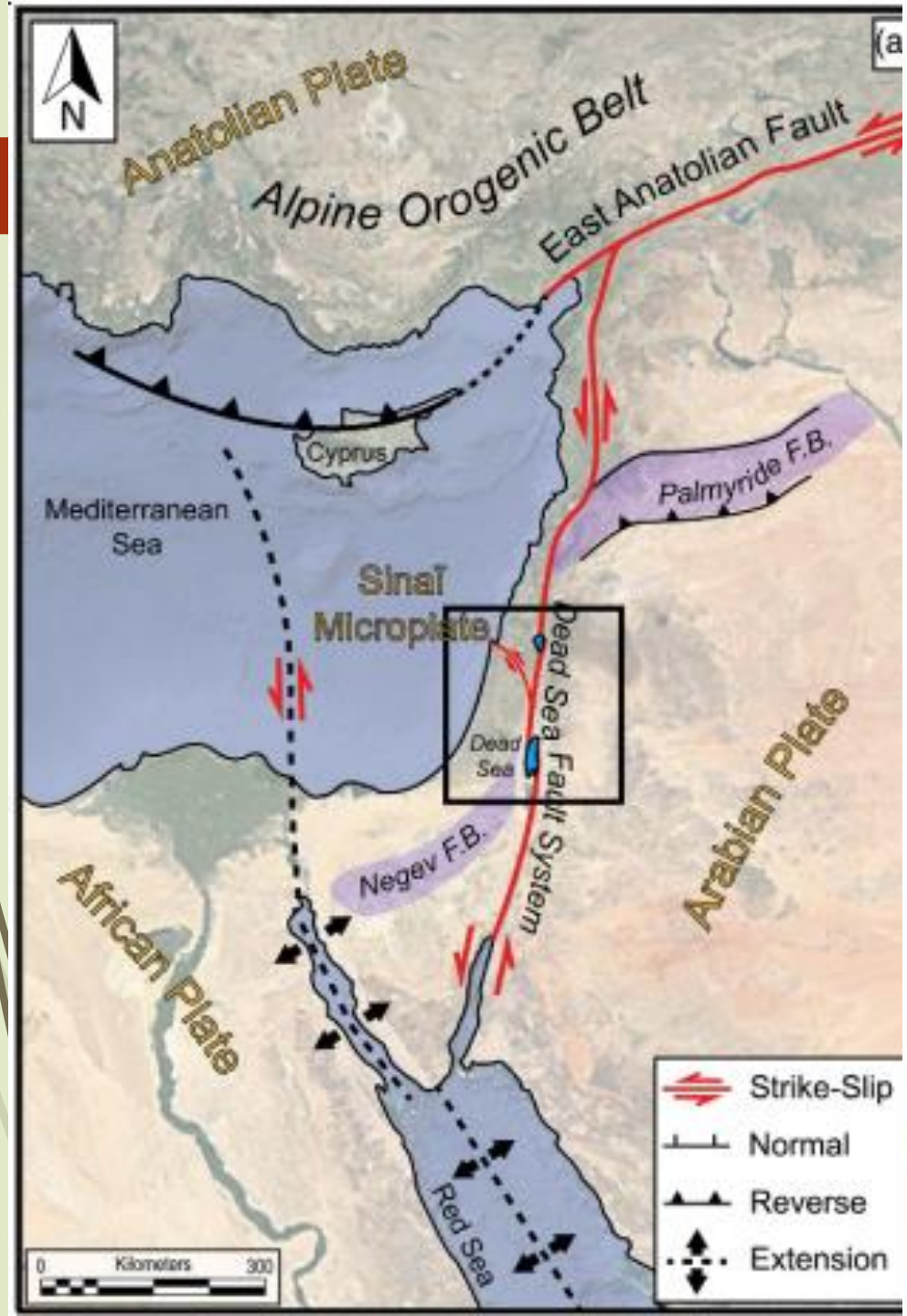
Projection		
Projection Method	TM	
scale	1.000 003	• The projected coordinate will be nearly same of classically reduced field distances to the MSL • As Gaza is the farthest from the central meridian, the distortion are minimized by rising the projection surface near the topography (with small extension 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"	

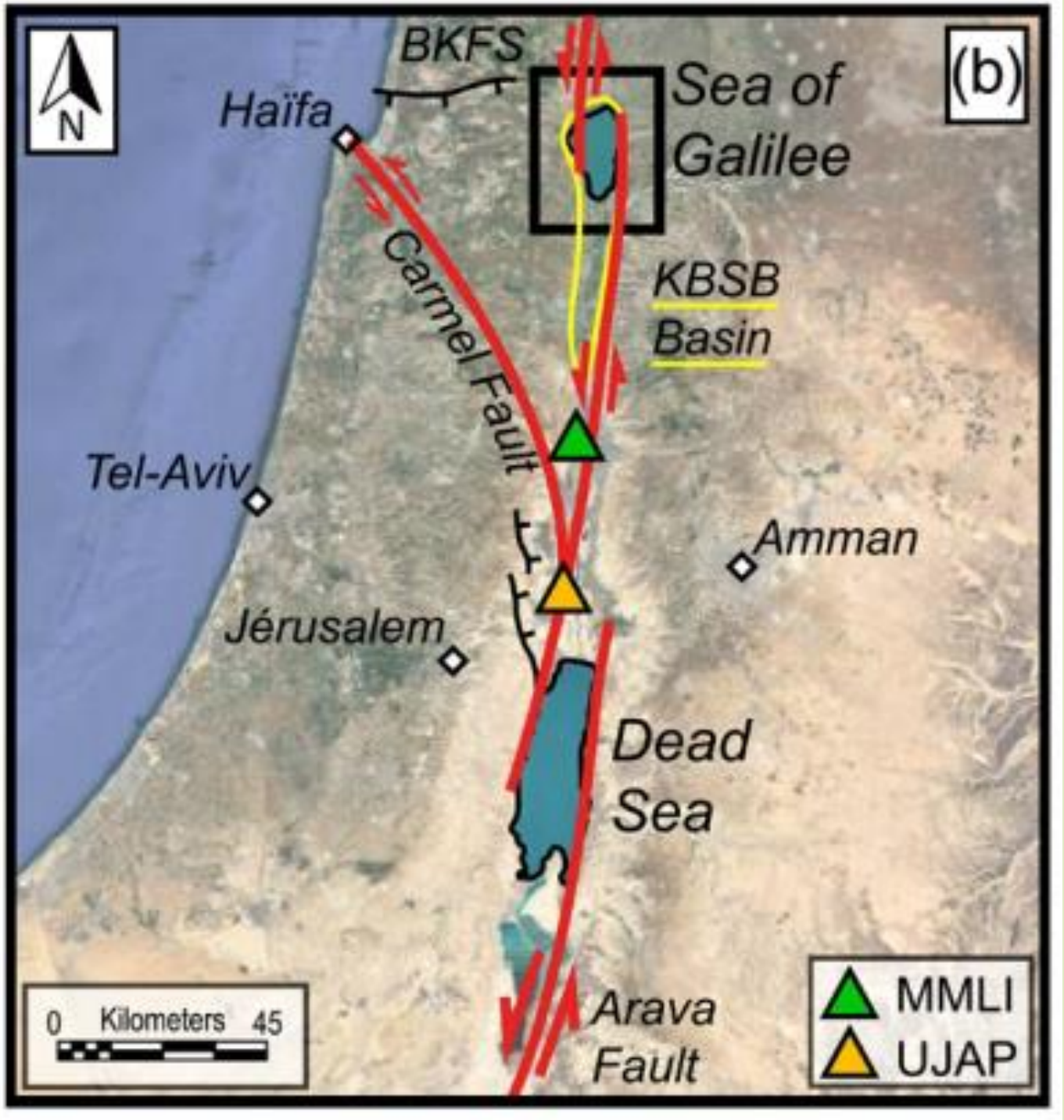
Parameter	Value
Ellipsoid	
Ellipsoid	GRS80
Semi-major axis (a)	6378137.00
Inverse flattening (f^{-1})	398.257 222 100 882
Semi-minor axis (b)	6356752.31414



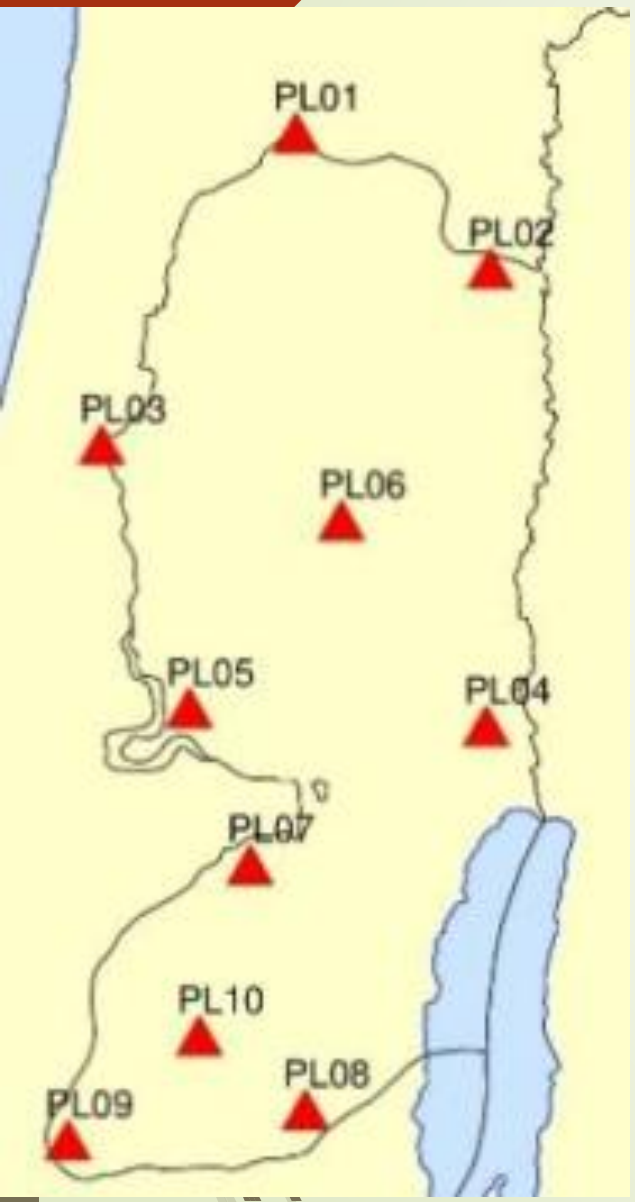


Used Global ITRF points


N
Anatolian Plate
Alpine Orogenic Belt
East Anatolian Fault
Cyprus
Mediterranean Sea
Palmyride F.B.
Sinai Microplate
Dead Sea Fault System
Dead Sea
Arabian Plate
Negev F.B.
African Plate
Red Sea
0 Kilometers 300
Strike-Slip
Normal
Reverse
Extension


N
(b)
BKFS
Haïfa
Sea of Galilee
Carmel Fault
KBSB Basin
Tel-Aviv
Amman
Jérusalem
Dead Sea
Arava Fault
0 Kilometers 45
MMLI
UJAP

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

2nd order – New vs Old

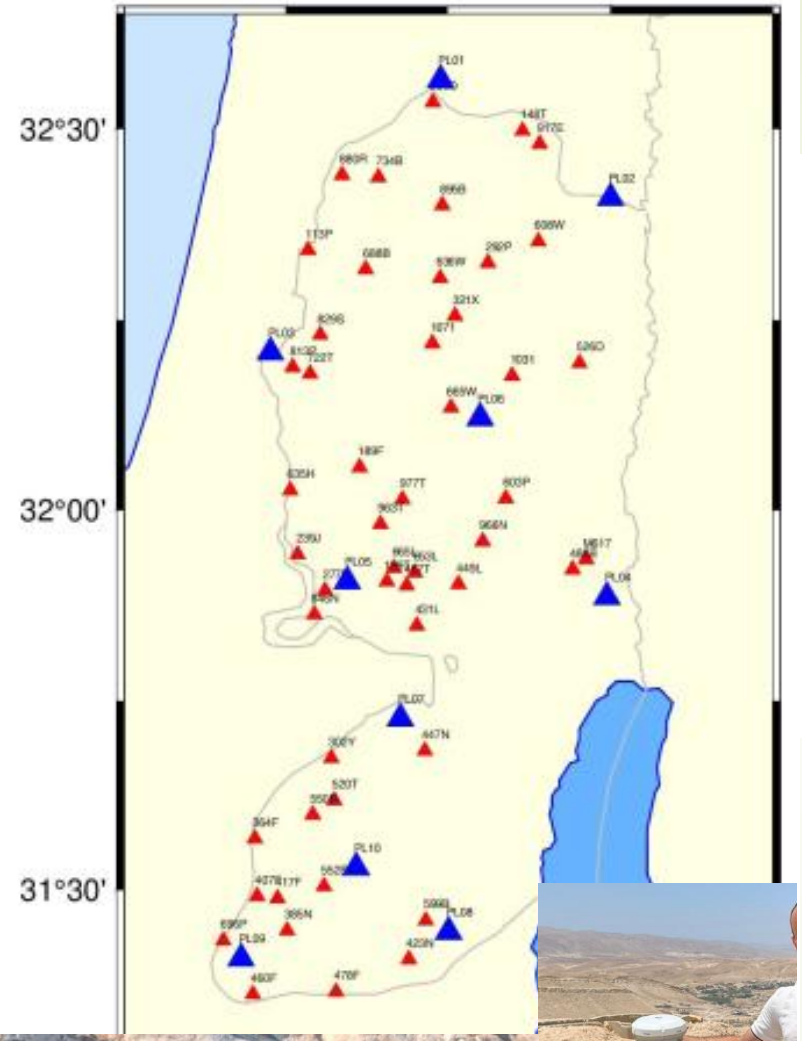


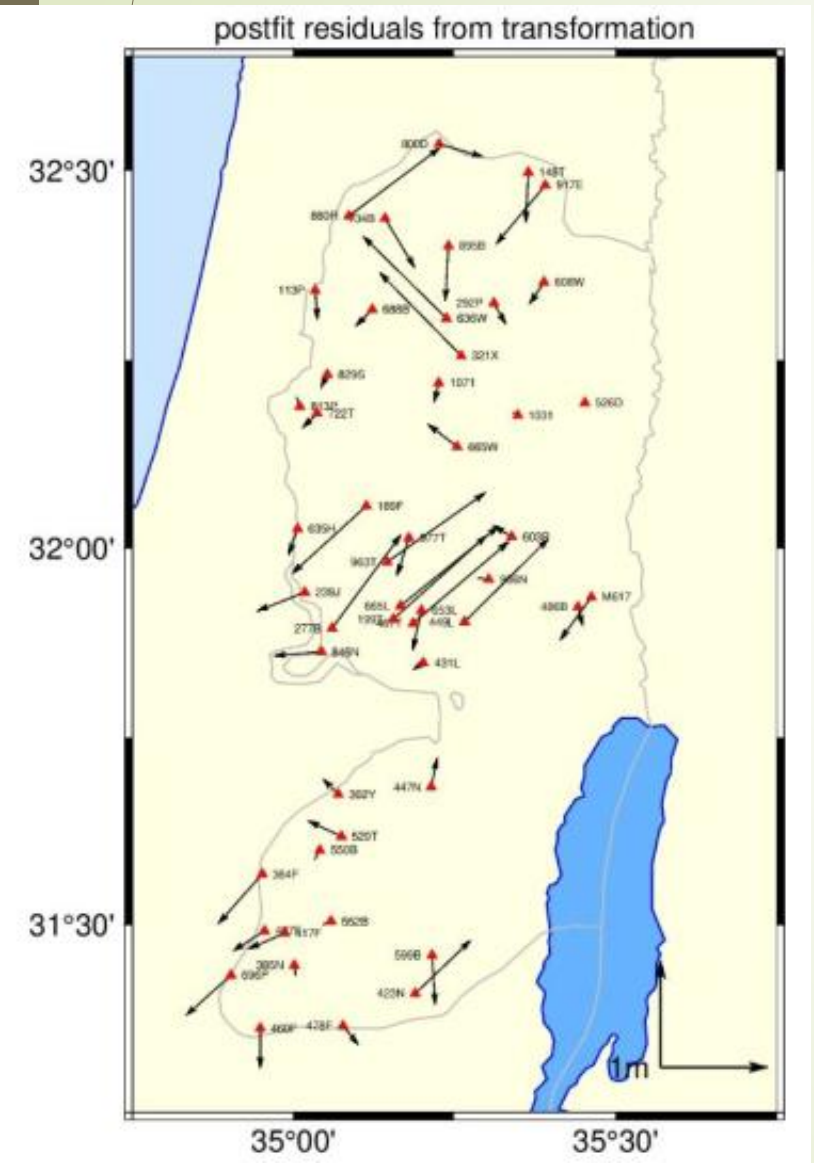
Table 11-4: The ITRF2020 coordinates of trig points used in the datum transformation

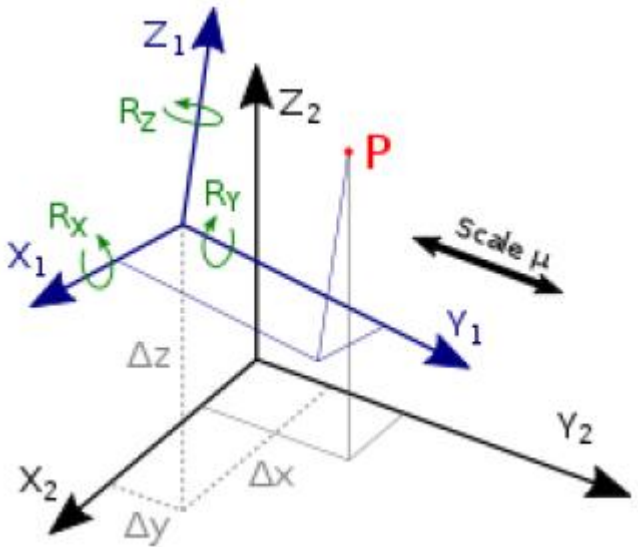
Station Name	Longitude	Latitude	Elipsoidal Height	X	Y	Z	Transversal Mercator	
	deg	deg	m	m	m	m	Easting (m)	Northing(m)
022Y	35.26221304	32.03197218	868.118	4419744.989	3124979.803	3363897.940	222570.56	528186.79
1031X	35.34820952	32.17660381	597.728	4407909.768	3126545.620	3377341.308	230677.00	544230.14
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	3108917.103	3354864.699	151800.86	149902.83

Connecting Pal-GRF2023 to Pal1923





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

3D Transformation Parameters (PAL-GRF to PAL1923)

$\Delta X = \quad 114.5200 \pm 14.8542$ m

$\Delta Y = \quad 79.3790 \pm 9.1074$ 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

$\delta = \quad 15.22329 \pm 1.23256$ ppm

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

conclusions

- The design and field work was done local
- The calculations were controlled by : AXIS-Palestine & MibMap-Turkey
- The high level of accuracy was achieved 1-3mm
- The system is accurately define with respect to earth kinematic & time related positioning
- The system is suitable for establishing GNSS Networks for public and private sector
- Soon: the system will announced as the official system for all surveys in Palestine.

What is next ?

- Extension to GAZA : 2 points were planned
- Active Network ?
- Regulat updatae and maintainance
- Transforming old surveys ←→ new surveys
- Developing more transformation method …