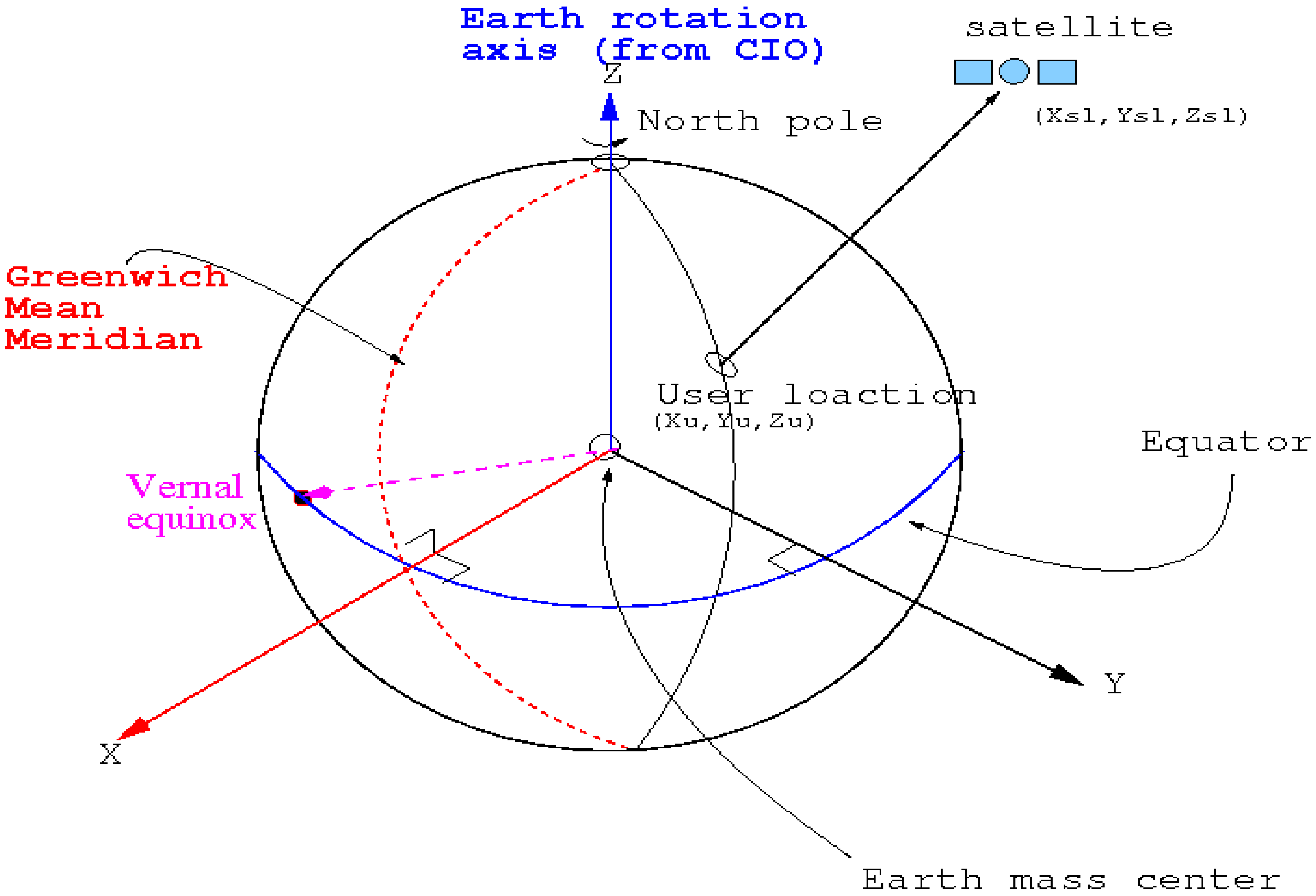
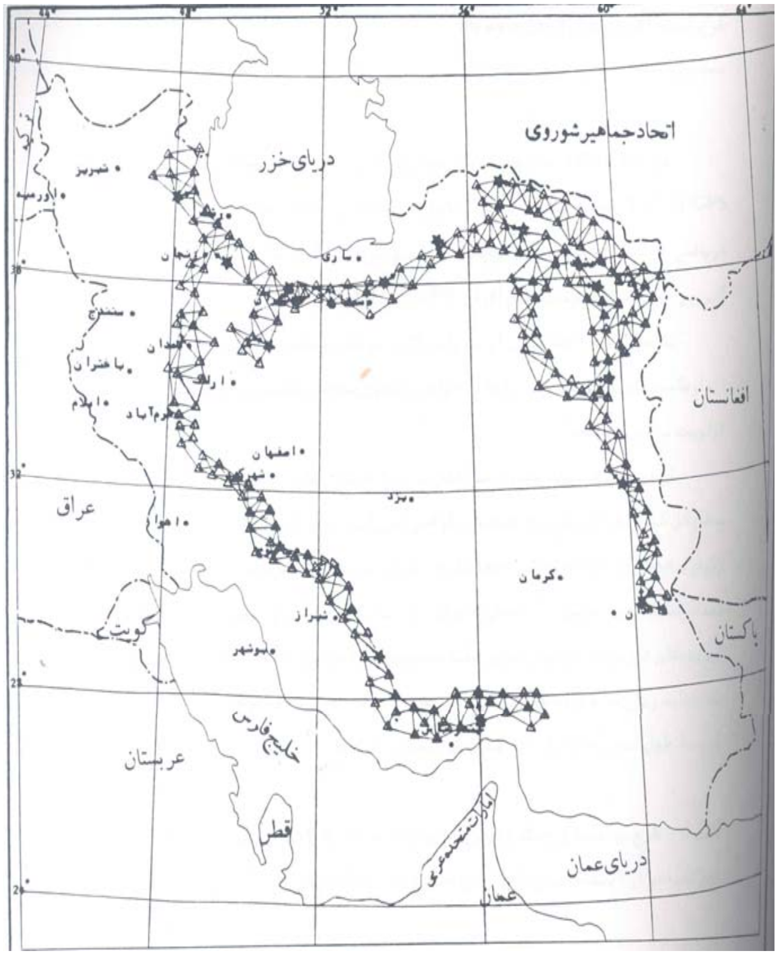
ITRF and WGS Realization

Terrestrial Reference System

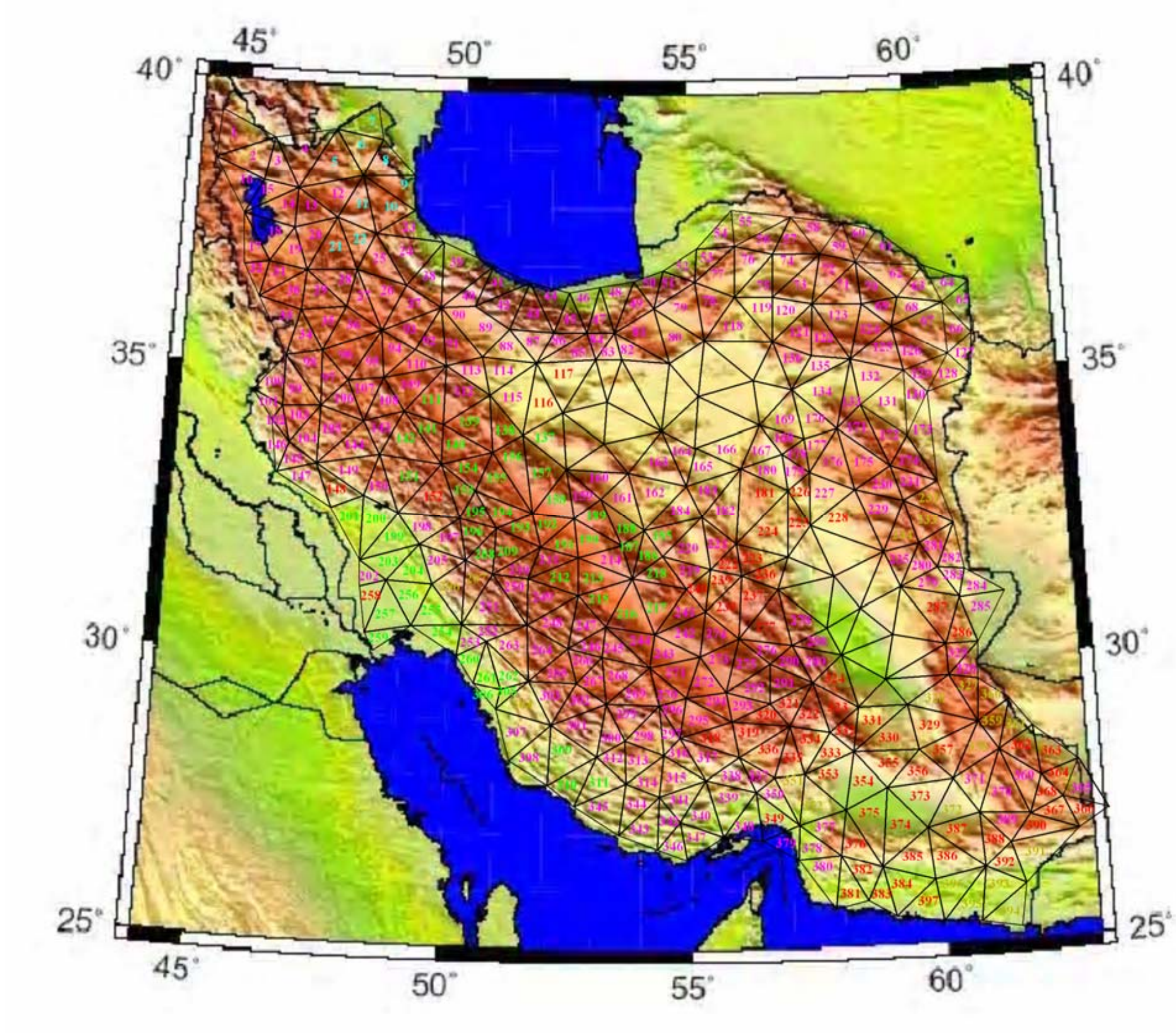


Classic Network

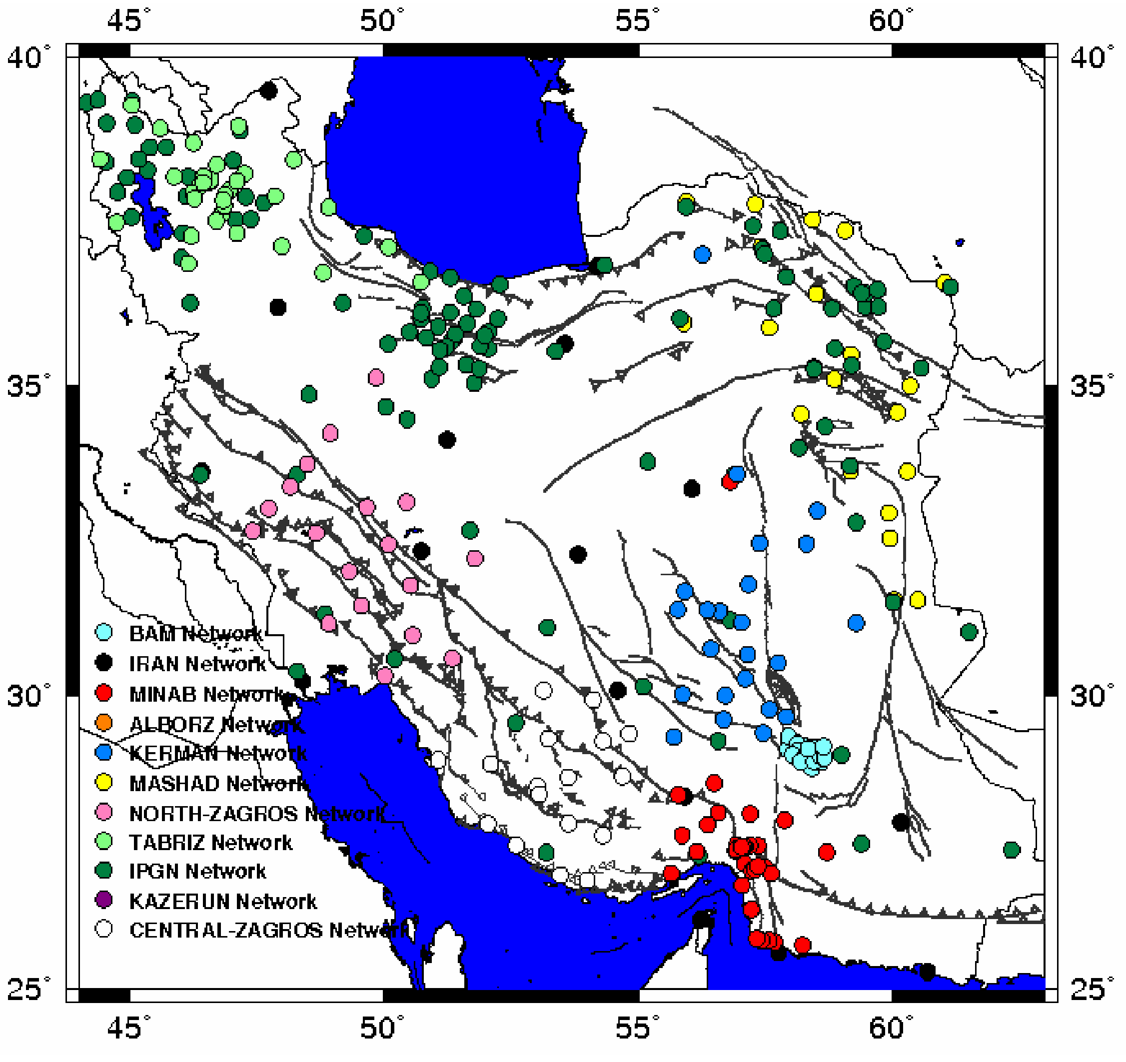
- 418 station
- Hayford 1924



1^{st} order GPS Network

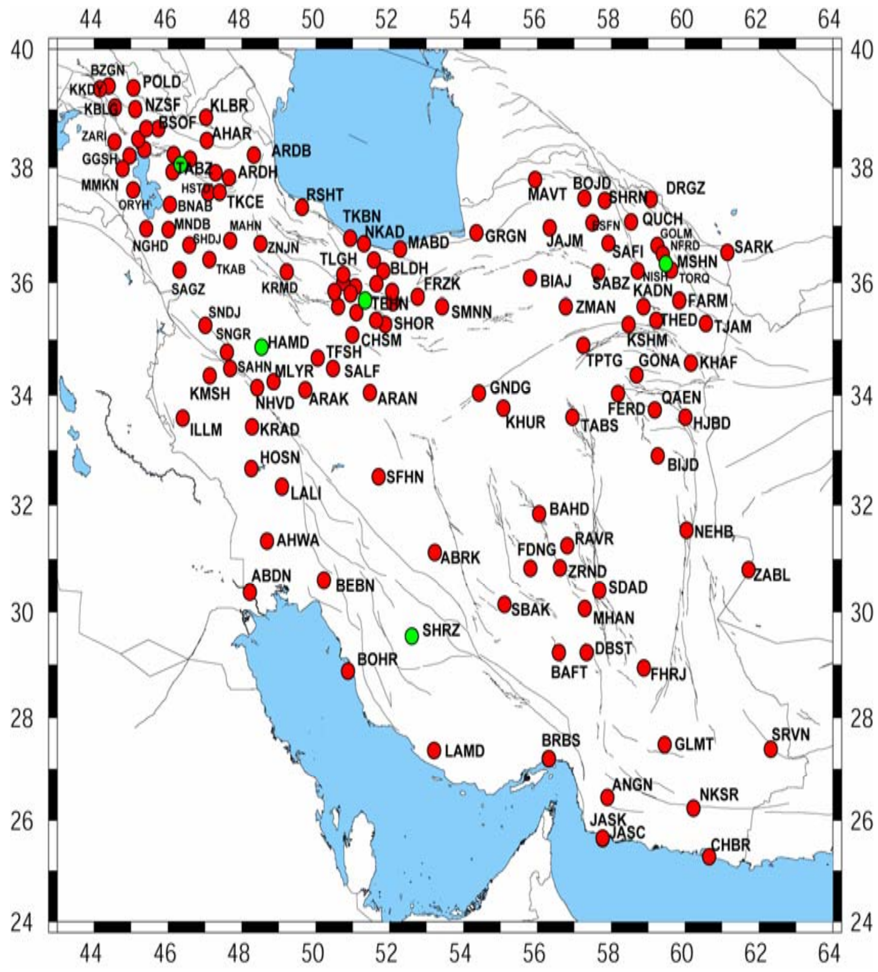


Campaign Network

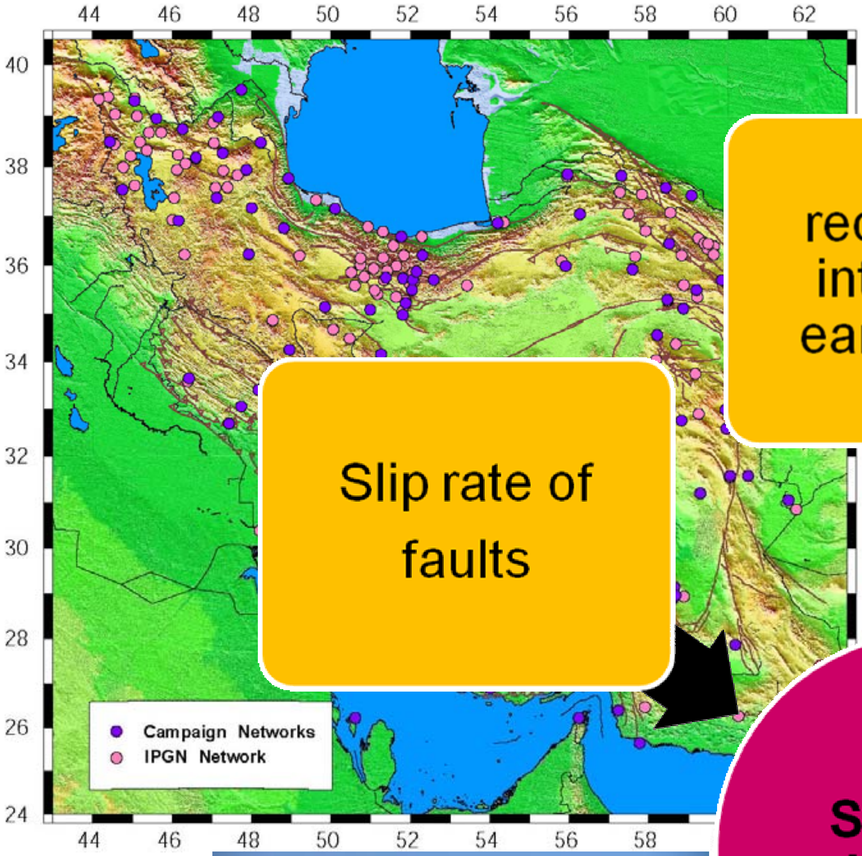


IPGN

- 135station
- Time span :20years
- Gamit-Globk
- ITRF2020



Iranian Permanent GPS Network (IPGN) for Crustal deformation monitoring

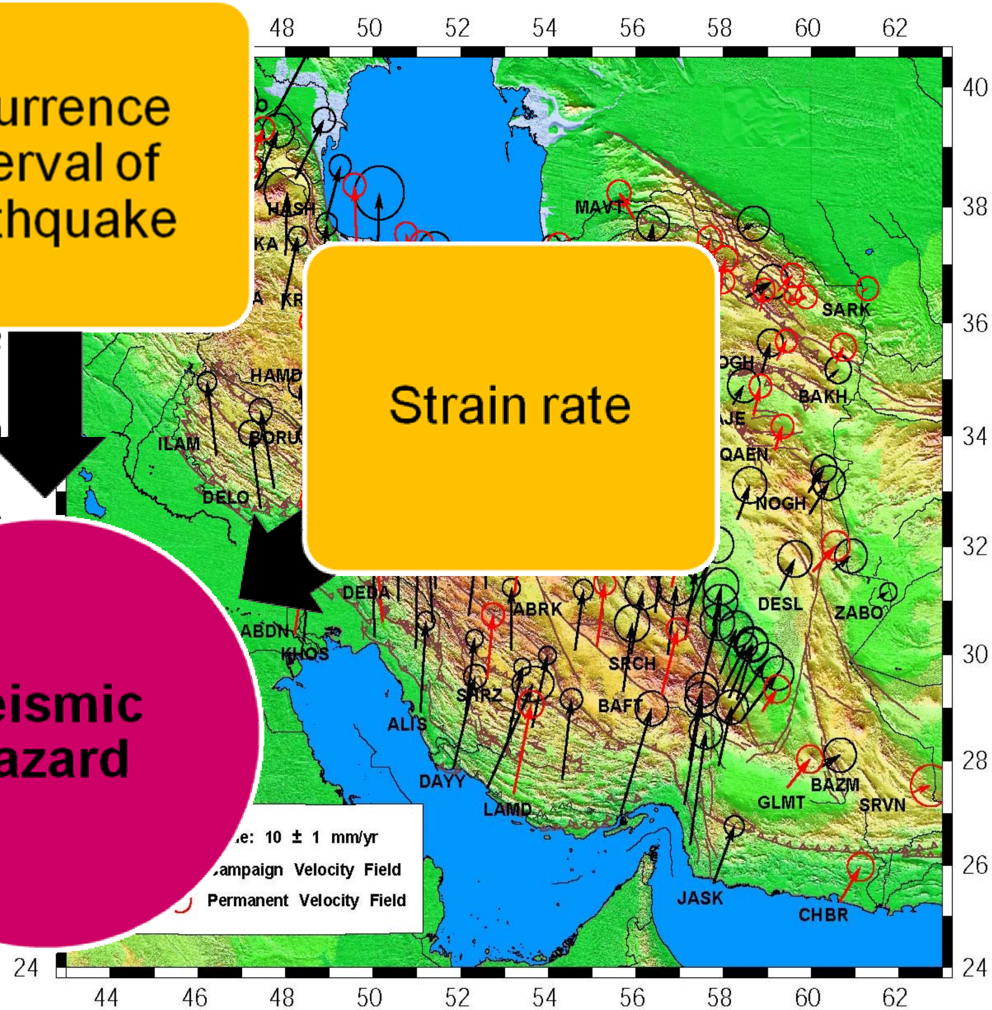


recurrence interval of earthquake

Slip rate of faults

Strain rate

Seismic hazard



velocity field of GPS networks relative to Eurasia plate

WGS84 definitions

- WGS84 is an Earth-centered, Earth-fixed terrestrial reference system and geodetic datum. WGS84 is based on a consistent set of constants and model parameters that describe the Earth's size, shape, and gravity and geomagnetic fields. WGS84 is the standard U.S. Department of Defense definition of a global reference system for geospatial information and is the reference system for the Global Positioning System (GPS). It is compatible with the International Terrestrial Reference System (ITRS). The current realization WGS84 (G1762) follows the criteria outlined in the International Earth Rotation Service (IERS) Technical Note 21 (TN 21).
- **Origin:** Earth’s center of mass being defined for the whole Earth including oceans and atmosphere.
- **Z-Axis**: The direction of the IERS Reference Pole (IRP). This direction corresponds to the direction of the BIH Conventional Terrestrial Pole (CTP) (epoch 1984.0) with an uncertainty of 0.005".
- **X-Axis**: Intersection of the IERS Reference Meridian (IRM) and the plane passing through the origin and normal to the Z-axis. The IRM is coincident with the BIH Zero Meridian (epoch 1984.0) with an uncertainty of 0.005".
- **Y-Axis**: Completes a right-handed, Earth-Centered Earth-Fixed (ECEF) orthogonal coordinate system.
- **Scale:** . Aligns with ITRS.
- **Orientation:** Given by the Bureau International de l’Heure (BIH) orientation of 1984.0.
- **Time Evolution:** Its time evolution in orientation will create no residual global rotation with regards to the crust.

ITRF

- An International Terrestrial Reference Frame (ITRF) is a realization of the International Terrestrial Reference System (ITRS), maintained by the International Earth Rotation and Reference Systems Service (IERS).

- A Terrestrial Reference System (TRS) is a spatial reference system co-rotating with the Earth in its diurnal motion in space. The ITRS imposes a no net rotation (NNR) condition for horizontal motions which means that the datum is not tied to any specific tectonic plate. In such a system, positions of points anchored on the Earth solid surface have coordinates which undergo only small variations with time, due to geophysical effects (tectonic or tidal deformations). A Terrestrial Reference Frame (TRF) is a set of physical points with precisely determined coordinates in a specific coordinate system (cartesian, geographic, mapping...) attached to a Terrestrial Reference System. Such a TRF is said to be a realization of the TRS.

- The ITRF solutions do not directly use an ellipsoid. ITRF solutions are specified by cartesian ECEF (Earth-Centered, Earth-Fixed) coordinates X, Y, and Z. If needed they can be transformed to geographical coordinates (Longitude, Latitude and Height) referred to an ellipsoid. In this case the GRS80 ellipsoid is recommended (semi-major axis a=6378137.0 m, flattening=1/298.257222101). This ellipsoid was adopted at the XVII General Assembly of the International Union of Geodesy and Geophysics (IUGG). The GRS80 reference system was originally used by the World Geodetic System 1984 (WGS84). The reference ellipsoid of WGS84 now differs slightly due to its later refinements.

- The current realization of the ITRS is the ITRF2014 solution, published by the IERS on 22 January 2016. The ITRF2014 solution replaces the ITRF2008 solution that was published by the IERS on 31 May 2010.

Crust-based TRF

The instantaneous position of a point on Earth Crust at epoch t could be written as :

$$X(t) = X_0 + \dot{X}.(t - t_0) + \sum_i \Delta X_i(t)$$

X_0 : point position at a reference epoch t_0

$\dot{X}$: point linear velocity

$\Delta X_i(t)$: high frequency time variations:

- Solid Earth, Ocean & Pole tides
- Loading effects: atmosphere, ocean, hydrology, Post-glacial-Rebound
- ... Earthquakes

How to express a GPS network in the ITRF ?

- Select a reference set of ITRF/IGS stations and collect RINEX data from IGS data centers;
- Process your stations together with the selected ITRF/IGS ones:
  - Fix IGS orbits, clocks and EOPs
  - Eventually, add minimum constraints conditions in the processing

  ==> Solution will be expressed in the ITRFyy consistent with IGS orbits

  - Propagate official ITRF station positions at the central epoch (t_c) of the observations:

$$X(t_c) = X(t_0) + \dot{X}(t_c - t_0)$$

  - Compare your estimated ITRF station positions to official ITRF values and check for consistency!

Transformation from an ITRF to another at epoch t_c

- **Input :** X (ITRFxx, epoch t_c)
- **Output:** X (ITRFyy, epoch t_c)
- **Procedure:**
  - Propagate ITRF transformation parameters from their epoch (2000.0, slide 72) to epoch t_c, for both ITRFxx and ITRFyy:

$$P(t_c) = P(2000.0) + \dot{P}(t_c - 2000.0)$$

  - Compute the transformation parameters between ITRFxx and ITRFyy, by subtraction;
  - Transform using the general transformation formula given at slide 8:

    X(ITRFyy) = X(ITRFxx) + T + D.X(ITRFxx) + R.X(ITRFxx)

Realization” of WGS 84 Reference Frame

- Defined (realized) by the coordinates of a globally-distributed set of reference points on the topographic surface of the Earth – constituted solely by a network of “permanent” GPS stations
- WGS 84 reference frame periodically adjusted to maintain close alignment to ITRF:

Positions of the reference points (DoD monitor stations) are estimated using GPS observations at these points combined with simultaneously-collected data from Int’l GNSS Service (IGS) stations roughly as follows:

1. Given:
   - High level of consistency between the WGS and ITRS conventions, constants and models
   - Known ITRF coordinates of IGS stations
2. Hold IGS station coordinates fixed* in the computations, solve for DoD station positions* and GPS satellite orbit parameters
3. Result: DoD station coordinates and by definition WGS 84 reference frame is coincident with the ITRF within some level of uncertainty

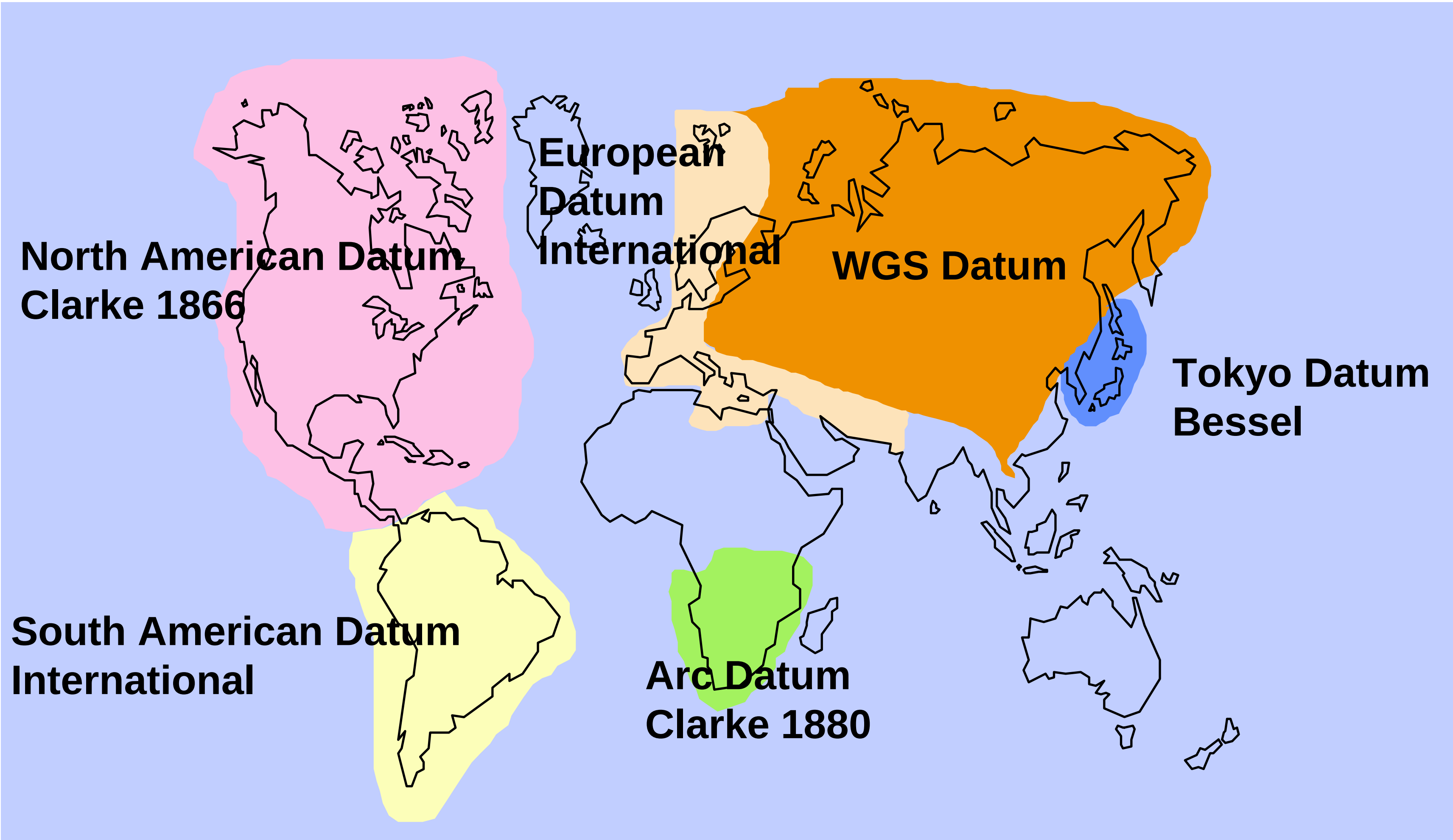
ITRF and WGS

- In general the ITRS (and its realizations ITRFyy) are identical to WGS84 at one meter level. Meanwhile there are two types of WGS84 realization.

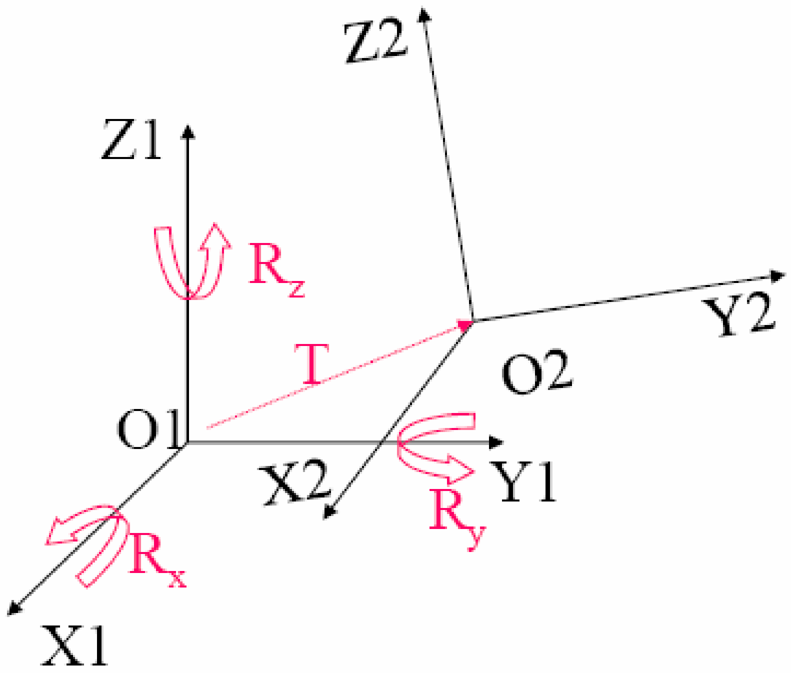
- Old realization based on U.S. Navy Navigation Satellite System, commonly known as DOPPLER Transit, and provided station coordinates with accuracies of about one meter. With respect to this realization the International Earth Rotation Service published transformation parameters between ITRF90 and this Doppler realized system: WGS84.TXT.

- New realizations of WGS84 based on GPS data, such as G730, G873 and G1150. These new WGS84 realizations are coincident with ITRF at about 10-centimeter level. For these realizations there are no official transformation parameters. This means that one can consider that ITRF coordinates are also expressed in WGS84 at 10 cm level. However, the most recent G1674 realization adopted ITRF2008 coordinates for more than half of the reference stations and velocities of nearby sites for the others. Thus, ITRF20014, ITRF2008 and WGS84 (G1674) are likely to agree at the centimeter level, yielding conventional 0-transformation parameters.

Where is the Datum Problem?



From one RF to another ?



$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_2 = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_1 + \begin{pmatrix} T_x \\ T_y \\ T_z \end{pmatrix} + \begin{pmatrix} D & -R_z & R_y \\ R_z & D & -R_x \\ -R_y & R_x & D \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_1$$