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Practical Considerations for the Determination of Euler Pole Parameters

Jacob Heck (jacob.heck@noaa.gov), Dan Roman, Dru Smith
National Geodetic Survey, National Oceanic and Atmospheric Administration, Silver Spring, MD, USA

Abstract

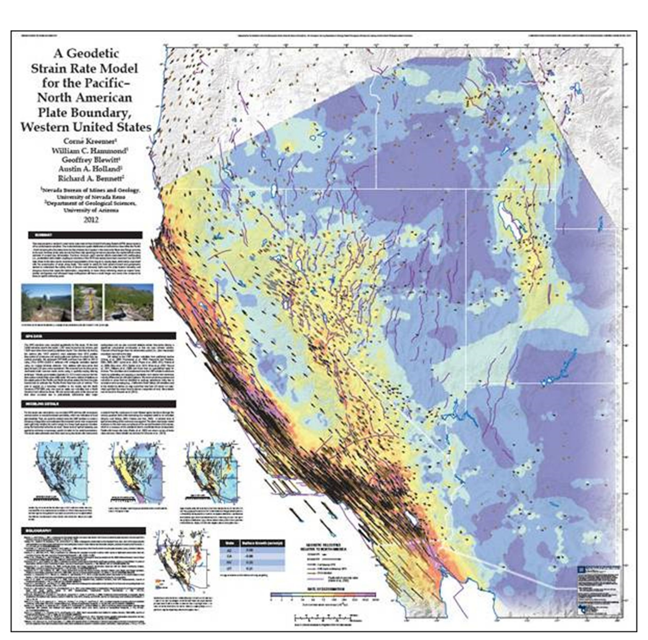
The National Geodetic Survey has stated that as part of National Spatial Reference System modernization, they will define four new terrestrial reference frames for the North American, Pacific, Caribbean and Mariana tectonic plates based upon IGS14 and the Euler Pole Parameters (EPPs) of the stable parts of those plates.
However, the determination of the rotation of the so-called “stable” part of any tectonic plate requires that several issues be resolved as part of the overall solution, including the definition of “stable”, the treatment of non-rotational horizontal secular and episodic motions, the availability of and quality of data, the use of non-GNSS methods in Euler pole determination and the stability of the Euler Pole itself. This poster will provide the current state-of-the-art for each of these issues for each of the four plates.

North American Plate

Much of the US land mass and population is located on the North American Plate, including parts of 49 states. Determination of the EPPs for North America will be done in conjunction with IAG SC 1.3c: North American Reference Frame (NAREF).

North American has:
- Lots of data (>2400 CORSs)
- Lots of studies into the rigid plate motion (Sella et al., 2002, etc.)
- Large, stable part of plate

Challenges:
- Alaska bending non-rigidly
- Plate boundary deformation west of the Rockies
- Hudson Bay uplift



Geodetic strain rate model for the Pacific-North American plate boundary, from Nevada Geodetic Lab (http://geodesy.unr.edu/greatbasinstrain.php)

(Below): Residual CORS velocities with the North American plate rotation removed.

The National Spatial Reference System will have 4 plate-fixed Terrestrial Reference Frames in 2022 to cover the 4 tectonic plates where there are significant US civilian populations:

- **North American Terrestrial Reference Frame (NATRF2022)**
- **Caribbean Terrestrial Reference Frame (CATRF2022)**
- **Pacific Terrestrial Reference Frame (PATRF2022)**
- **Mariana Terrestrial Reference Frame (MATRF2022)**

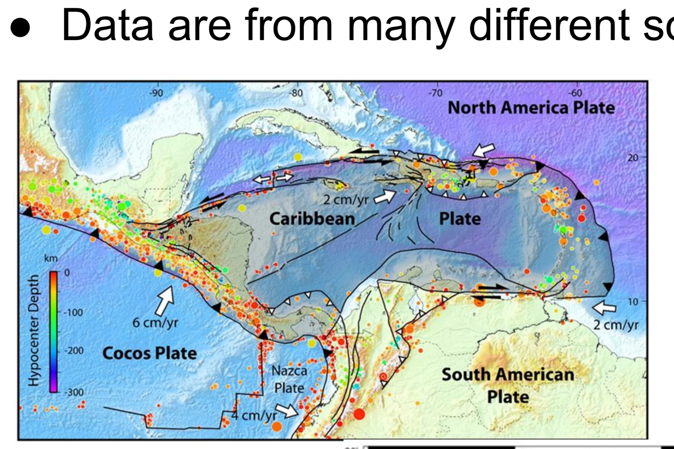
Coordinates anywhere can be computed in any of the TRFs, but they will have larger time variations if computed in a frame that is not “attached” to the plate where the site is located.

A plate-fixed frame is simply the ITRF frame with the rotation of one plate removed. The modernized NSRS will use plate rotations as are characterized 3 parameters:
- Micro-rotational rate about ITRF2014 X axis (mas/year)
- Micro-rotational rate about ITRF2014 Y axis (mas/year)
- Micro-rotational rate about ITRF2014 Z axis (mas/year)

Euler pole latitudes, longitudes, and rotation rates can be derived from the micro-rotation rates about the X, Y, and Z axes. Residual motion will be accounted for in an Intra-Frame Velocity Model (IFVM). All motion at a point can be accounted for as a combination of plate rotation and IFVM.

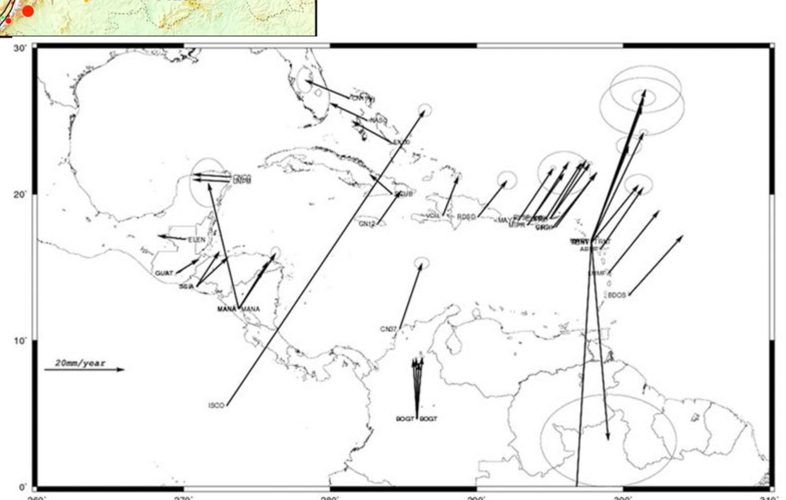
Caribbean Plate

The Caribbean plate is located within and around the Caribbean Sea. Puerto Rico and the U.S. Virgin Islands are located on this plate. NGS will work in conjunction with SIRGAS and IAG Commission 1.3b to define the rotation of this plate for the NSRS. The Caribbean plate is a small plate, dense with CORSs, however it presents several challenges:
- Almost all land is deforming at the edge
- Plate boundary is not completely known in the north
- Data are from many different sources/networks

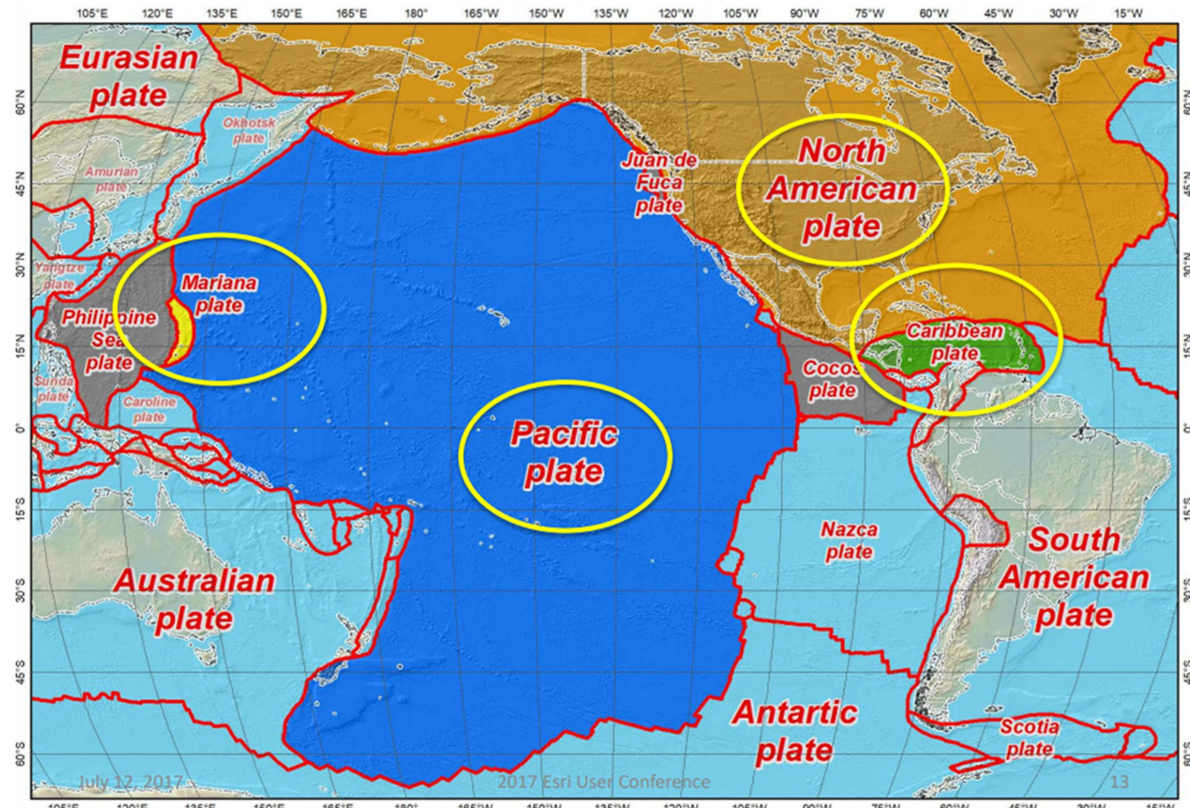


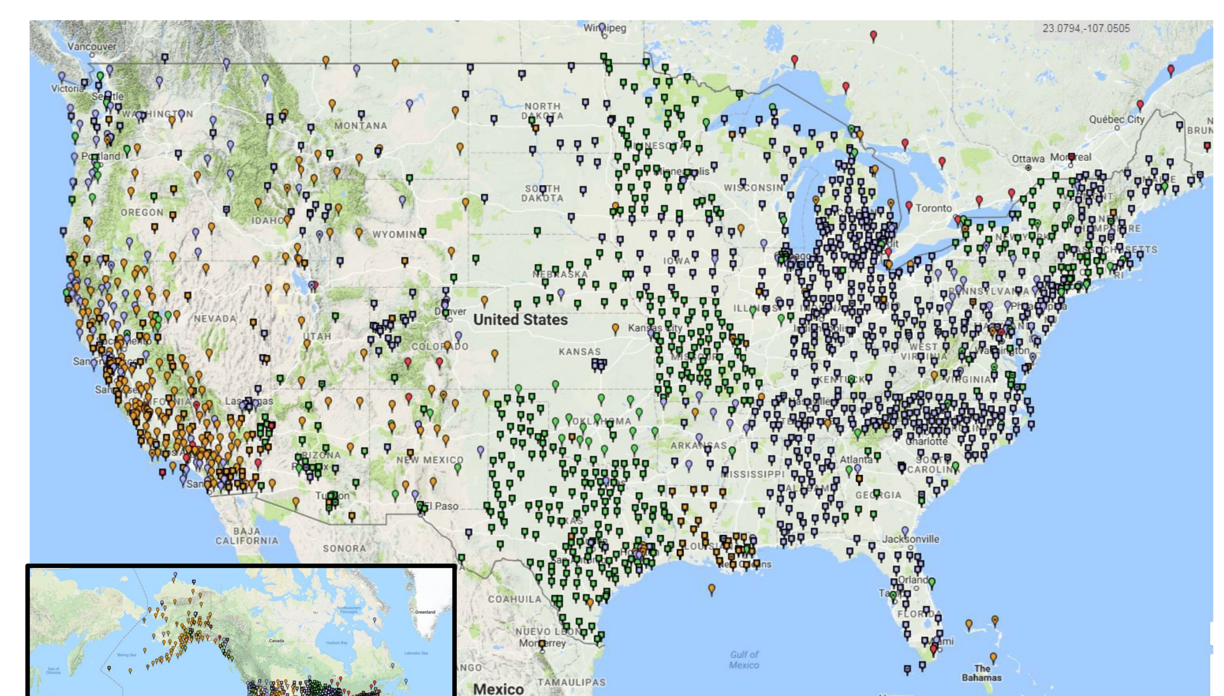
(left): Deformation within the Caribbean plate (From DeMets 2007).

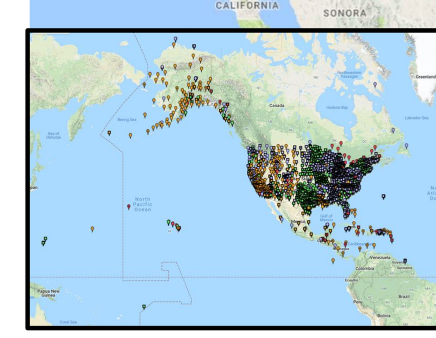
(below): IGS08 velocities of the CORS stations within the Caribbean.



The four tectonic plates “fixed” for the 2022 terrestrial reference frames







Locations of CORSs in CONUS (above) and across the four plates (left).

Pacific Plate

The Pacific plate is mostly oceanic. In places where it has land such as southwestern California, Hawaii, and Samoa, there are many CORSs (>100) for data to use to derive the EPPs. NGS will work to align PATRF with the Asia-Pacific Reference Frame (APREF), which is part of IAG Subcommission 1.3e.

Challenges:
- Mostly ocean
- Many places are deformation zones (at plate boundary or on active volcanoes)

References

1. Altamimi, Z., L. Métivier, P. Rebischung, H. Rouby, X. Collilieux (2017). ITRF2014 plate motion model, Geophys. J. Int., 209, 1906–1912.
2. Bird, P (2003) An updated digital model of plate boundaries. Geochemistry, Geophysics, Geosystems (AGU and the Geochemical Society) 4 (3).
3. DeMets, C., et al. (2007) Present motion and deformation of the Caribbean plate: Constraints from new GPS geodetic measurements from Honduras and Nicaragua. In: Geological Society of America Special Paper 428.
4. National Geodetic Survey (2017) Blueprint for 2022, Part 1: Geometric Coordinates. NOAA Technical Report NOS NGS 62.
5. Sella, G. F, T. H. Dixon and A. Mao (2002) REVEL: A model for Recent plate velocities from space geodesy. Journal of Geophysical Research 107: B4,2081-2111.

Data Availability and Sources

While velocity vectors from CORSs are the primary data to use in Euler pole determination, the motions of these sites can be reflective of local effects instead of rigid plate motion. Slumping, earthquake activity, and volcanic activity can influence the motion of the site and data gaps in a timeseries can lead to poor estimates of motion. Long timeseries make for better velocity estimates at these stations. Earthquakes and equipment changes can cause jumps in the time series as well. Sites near plate boundaries are inherently unstable and do not necessarily reflect the overall motion of the rigid plate, therefore boundary sites are eliminated.

Ideally sites will be used with:
- Long data time spans (several years at least) and few data gaps
- Demonstrated stability
- Located in a stable region

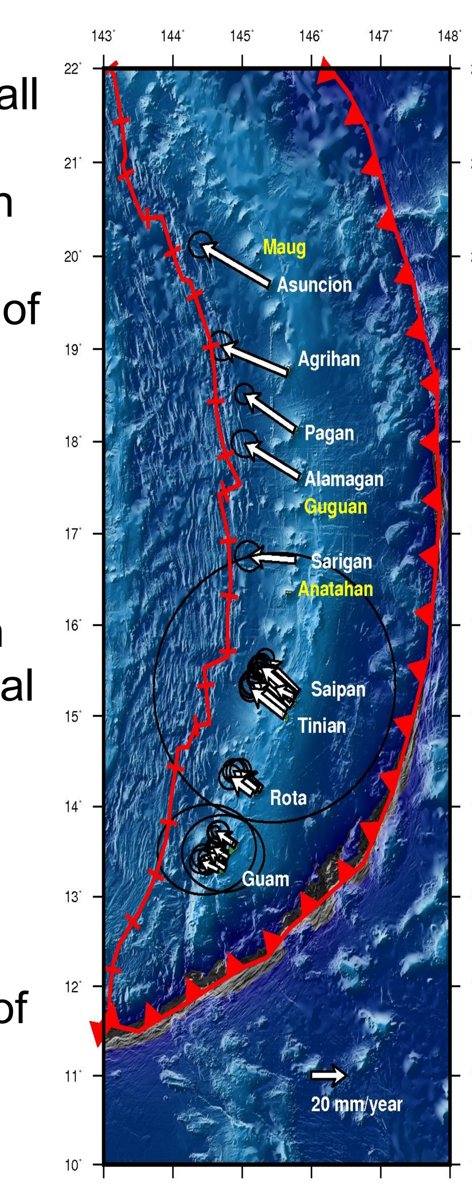
Non-CORS data sources include: Survey GPS data, Paleomagnetic data (seafloor spreading rates), focal mechanisms and earthquake slip vectors, transform fault geometry, and IfSAR.

Mariana Plate

The Mariana plate is a very small plate between the Pacific and Philippine plates at the western edge of the Pacific Ocean. Guam and the Commonwealth of the Northern Mariana Islands (CNMI) are located here. NGS will work with IAG Subcommission 1.3e (APREF) for the determination of EPPs. The few studies that have been done show clear rotational signal in the plate.

NGS went in 2017 to perform a survey to specifically develop a rotational model. This survey performed repeat occupations of survey marks using campaign GPS measurements.

Challenges:
- Contaminated by deformation
- Many large (>Mw6.5) earthquakes
- Only 5 CORSs have ever operated on the plate, 1 has been non-operational for many years, 1 is non-NGS, all in the southern ⅓ of the plate.



Survey GPS velocity vectors at stations on the Mariana plate. From Smith (2019, in review).