Modernizing the National Spatial Reference System in 2022:

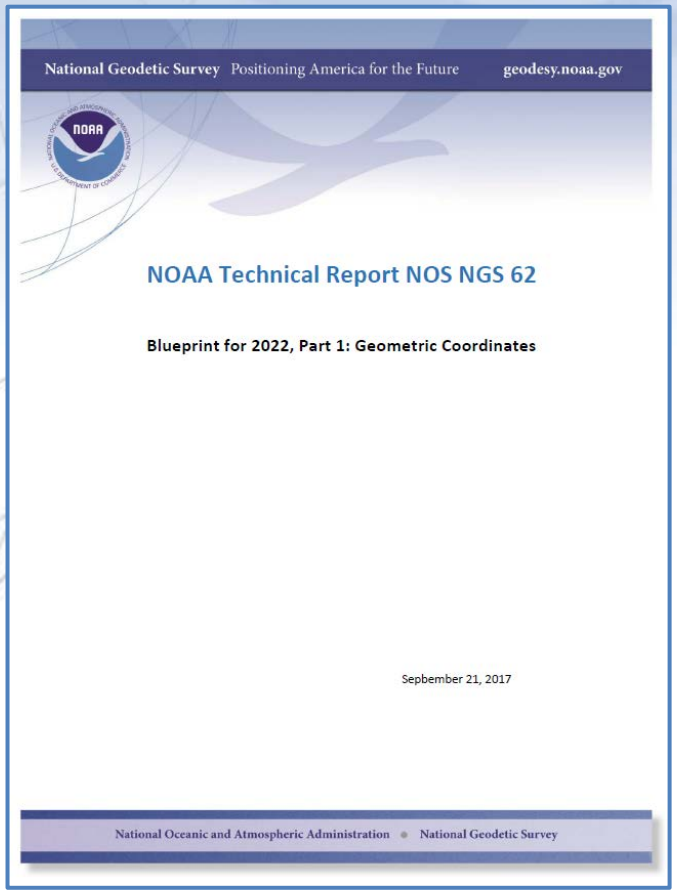
What's New?

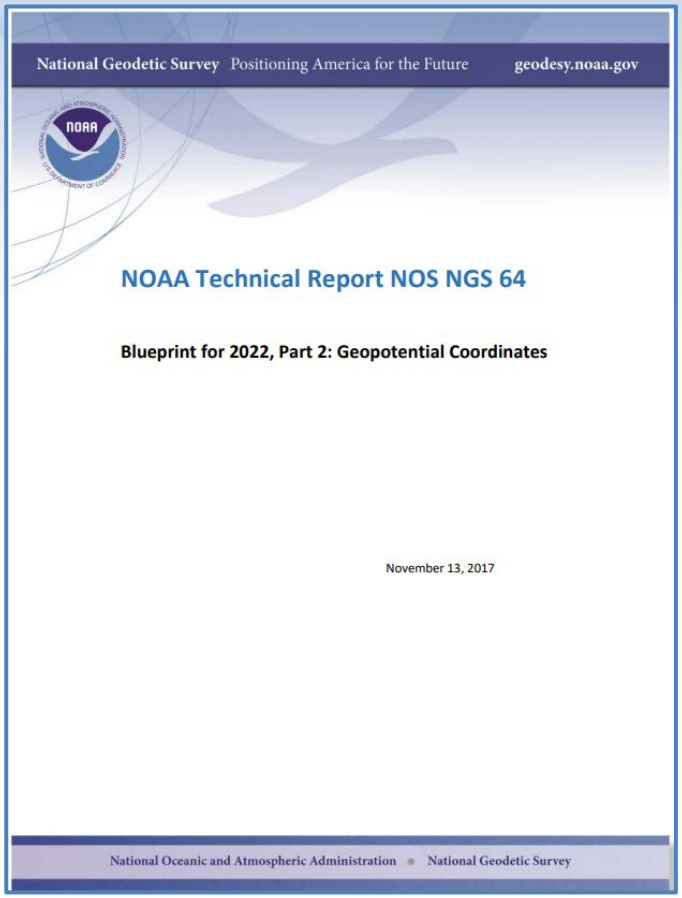
NOAA's National Geodetic Survey

Some old, some new*

- Blueprints*
- Why replace NAD 83 & NAVD88?
- What's being replaced?
- Four Terrestrial Reference Frames
- Intra-Frame Velocity Model*
- Hybrid Geoid18*
- Foundation CORS*
- Adding RTK vectors to OPUSprojects*

Blueprints Part 1 and Part 2 published





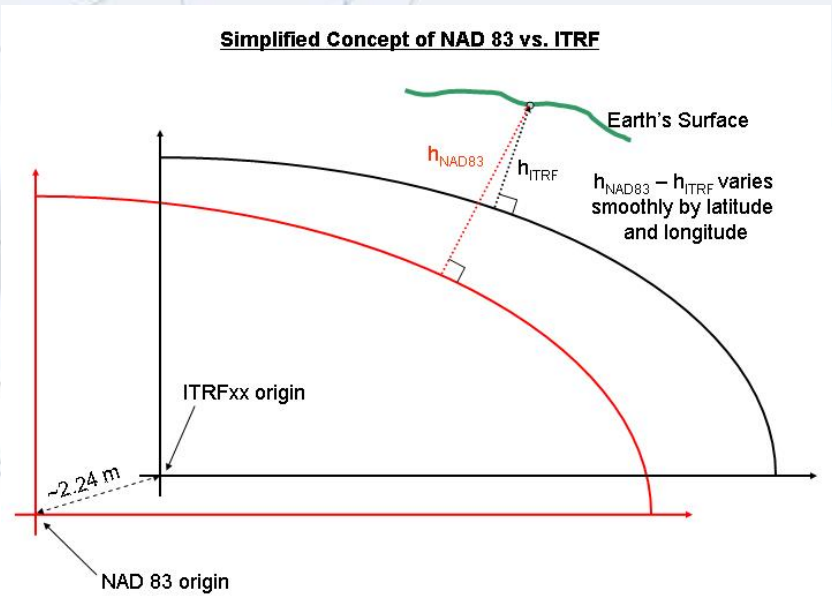
If you remember nothing else from this talk, remember to just search for "**Blueprint 2022**" in any search engine

Coming Soon

- Blueprint for 2022, Part 3: Using the Modernized NSRS
  - Should address questions about how to work in a system that uses *time-dependent* geodetic control

Why Change?

- Non-Geocentricity



- Dynamism

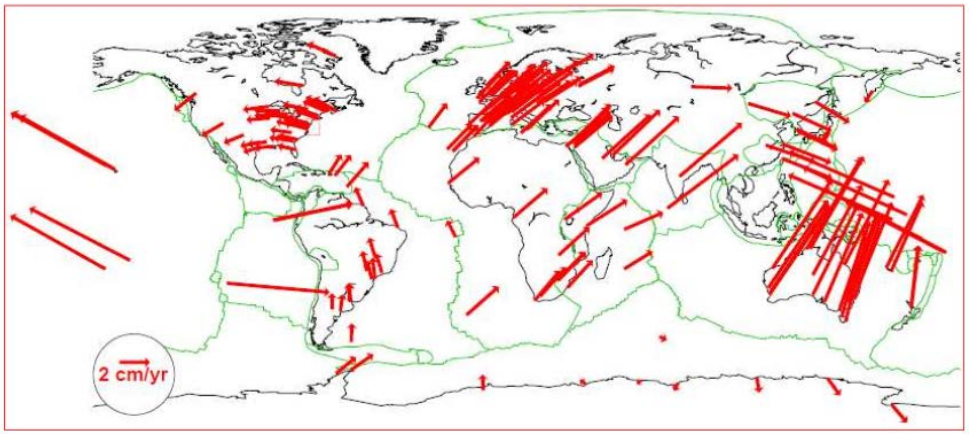


Figure 1. Horizontal velocities of the 203 selected sites for the ITRF2008 PMM estimation

Geopotential Datum Modernization

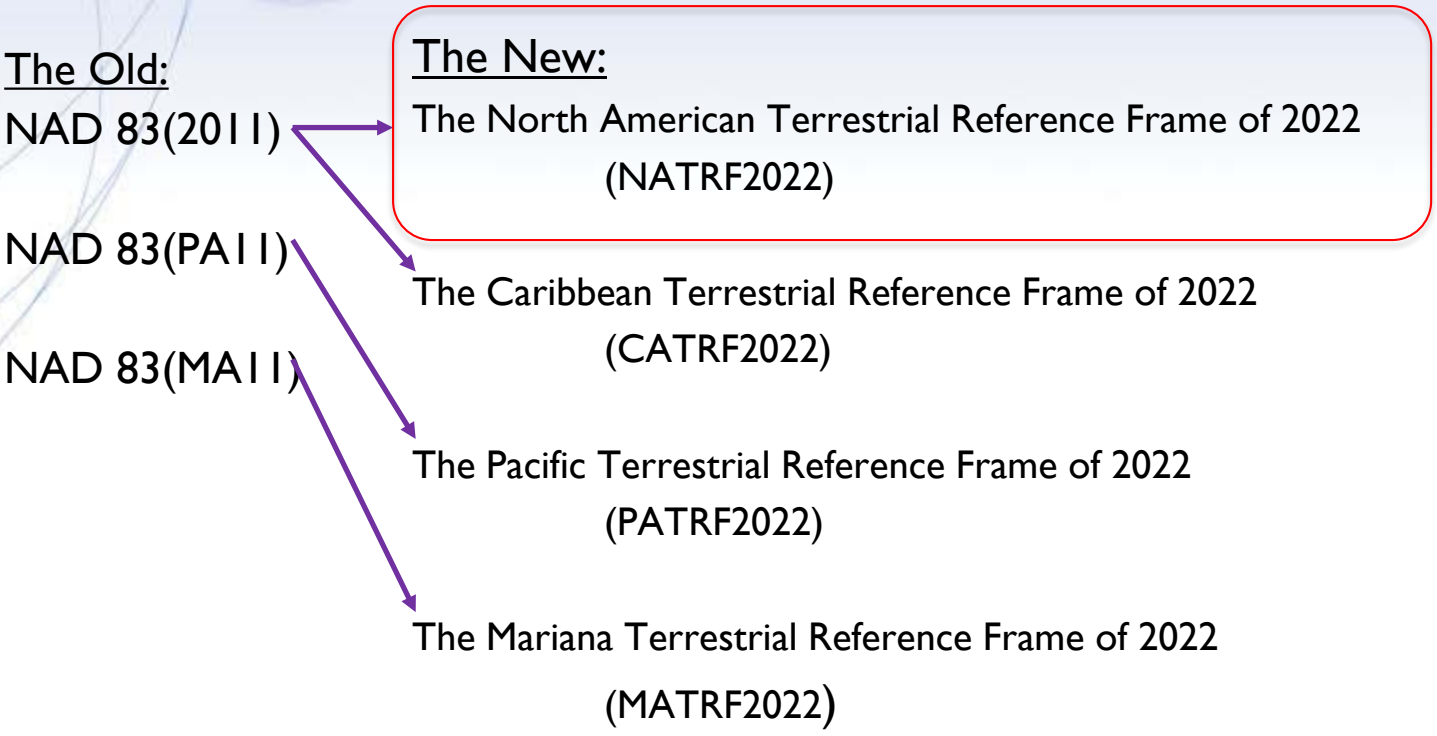
	The Old:
Orthometric Heights	NAVD 88
Normal Orthometric Heights	PRVD 02
	VIVD09
	ASVD02
	NMVD03
	GUVD04
Dynamic Heights	IGLD 85
Gravity	IGSN71
Geoid Undulations	GEOID12B
Deflections of the Vertical	DEFLEC12B

The New:

The North American-Pacific Geopotential Datum of 2022 (NAPGD2022)

- Primary component is a **global** harmonic model of geopotential which includes all GRAV-D data:
  - GM2022
- Related **regional** gridded products:
  - GEOID2022
  - DEFLEC2022
  - GRAV2022

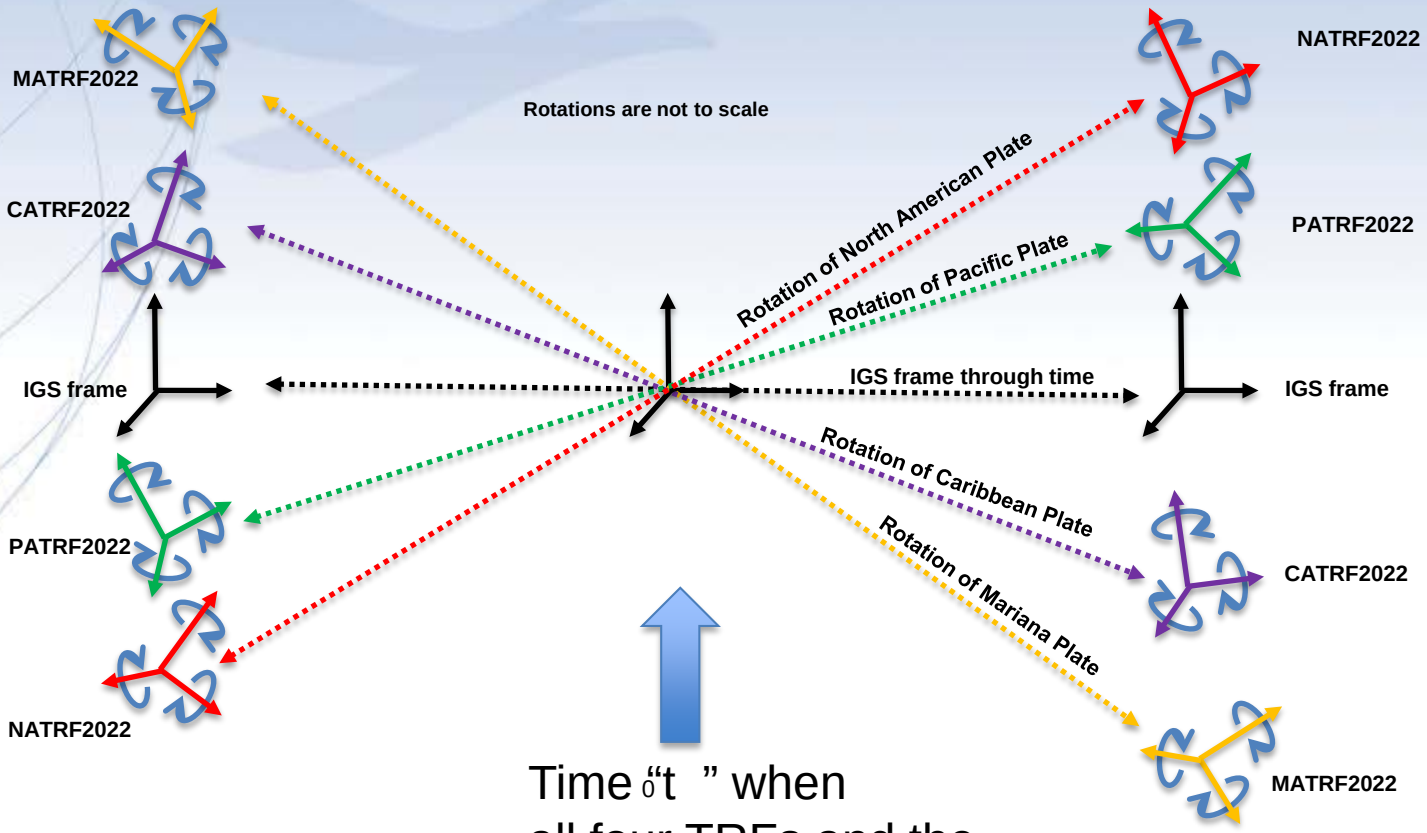
NSRS Geometric Modernization



Geometric Reference Frames

- The NSRS in 2022 will contain four terrestrial reference frames
  - Each one related to the IGS frame by a plate rotation model *only*
    - This will leave *residual* velocities.
      - Why?
        - » Because every point on Earth is moving for many reasons, and plate rotation, while large, is not the only thing happening to points.
    - NGS will model those residual velocities in an Intra-Frame Velocity Model (IFVM)

The relation of five global reference frames through time.

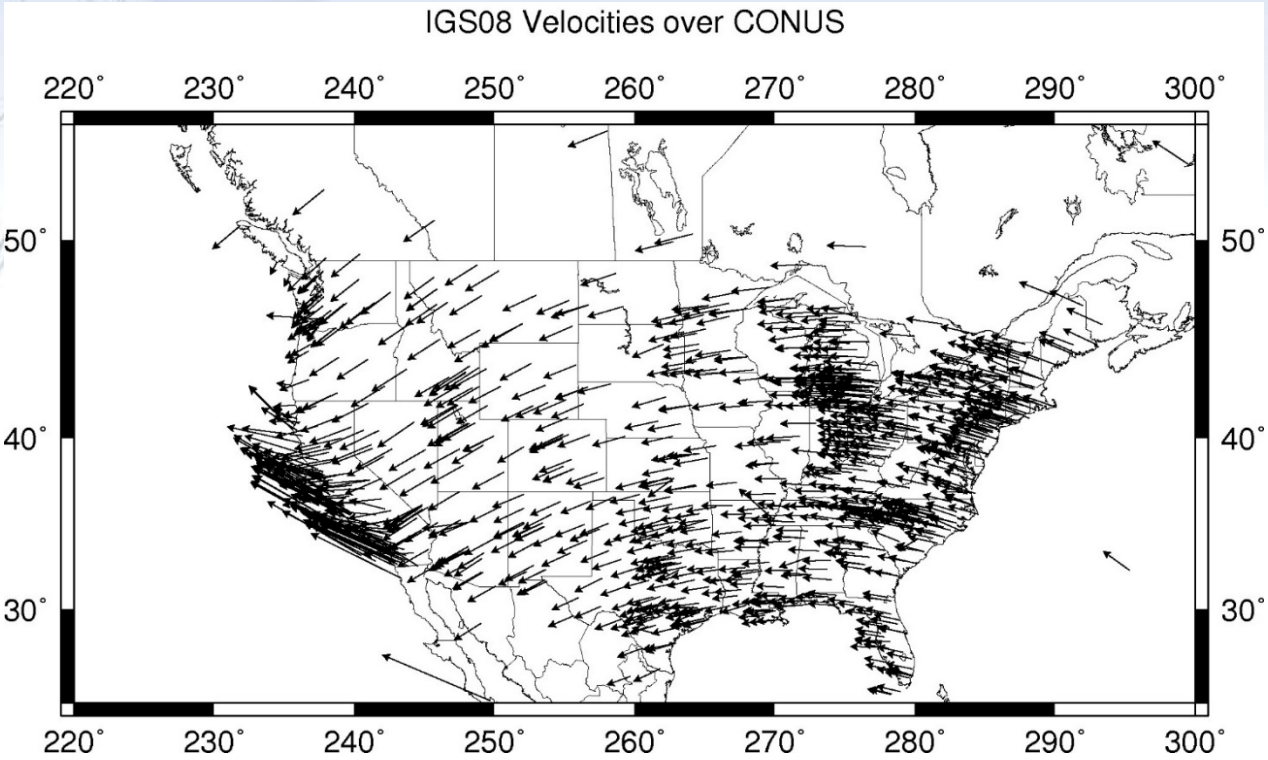


Time "t " when all four TRFs and the IGS are identical. (2020.00)

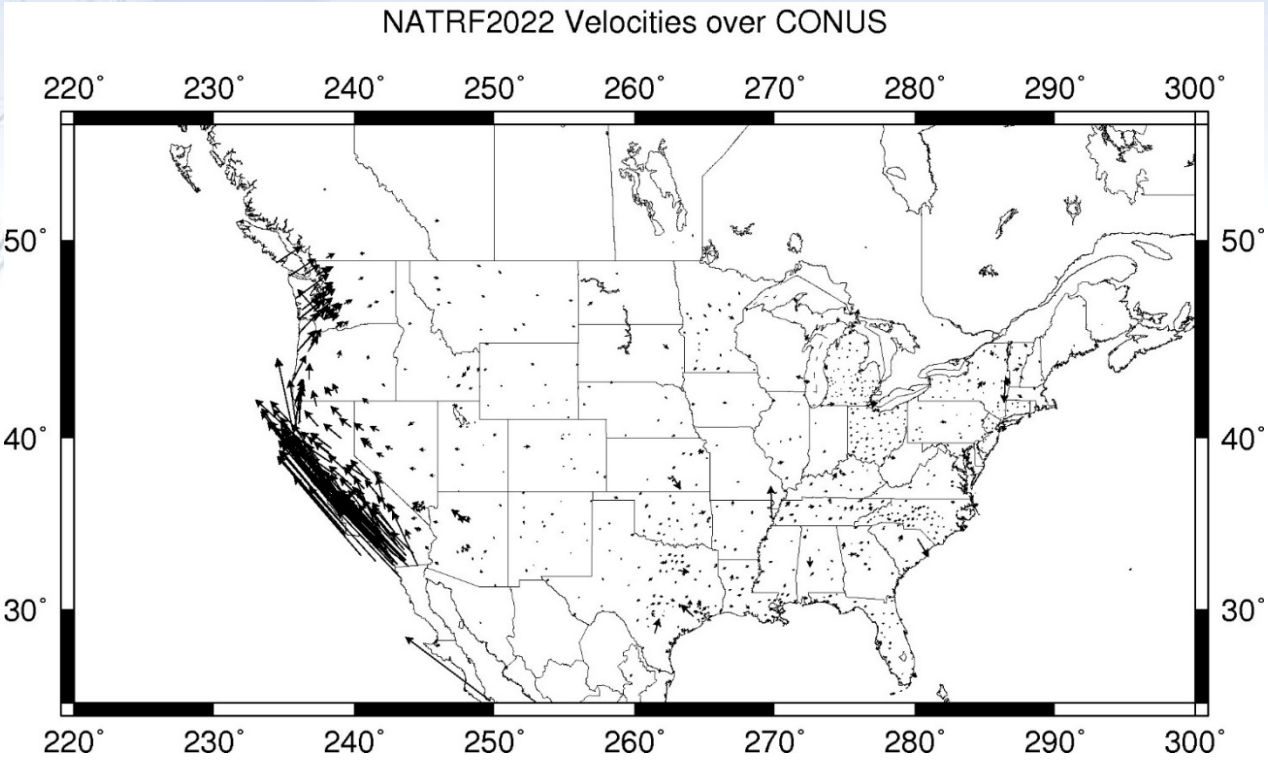
t=t - Δt ("the past")

t=t + Δt ("the future")

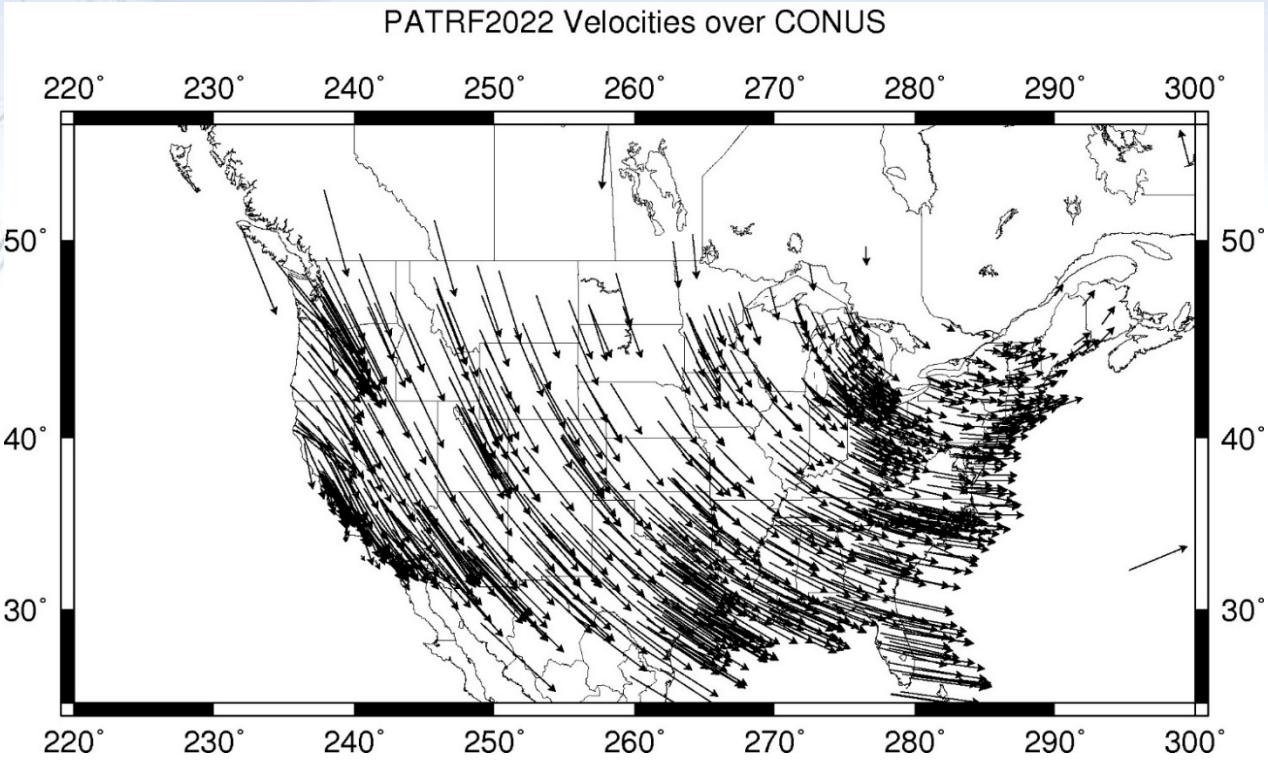
CORS Velocities – IGS08



CORS Velocities – NATRF2022



CORS Velocities – PATRF2022

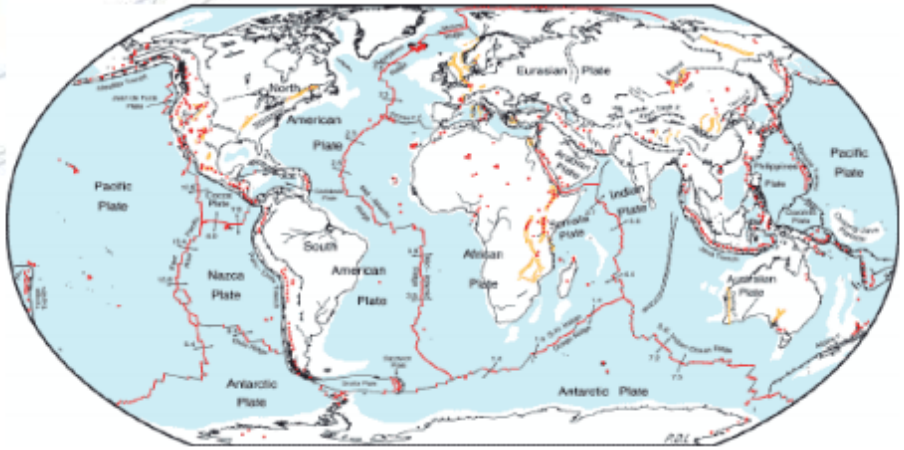


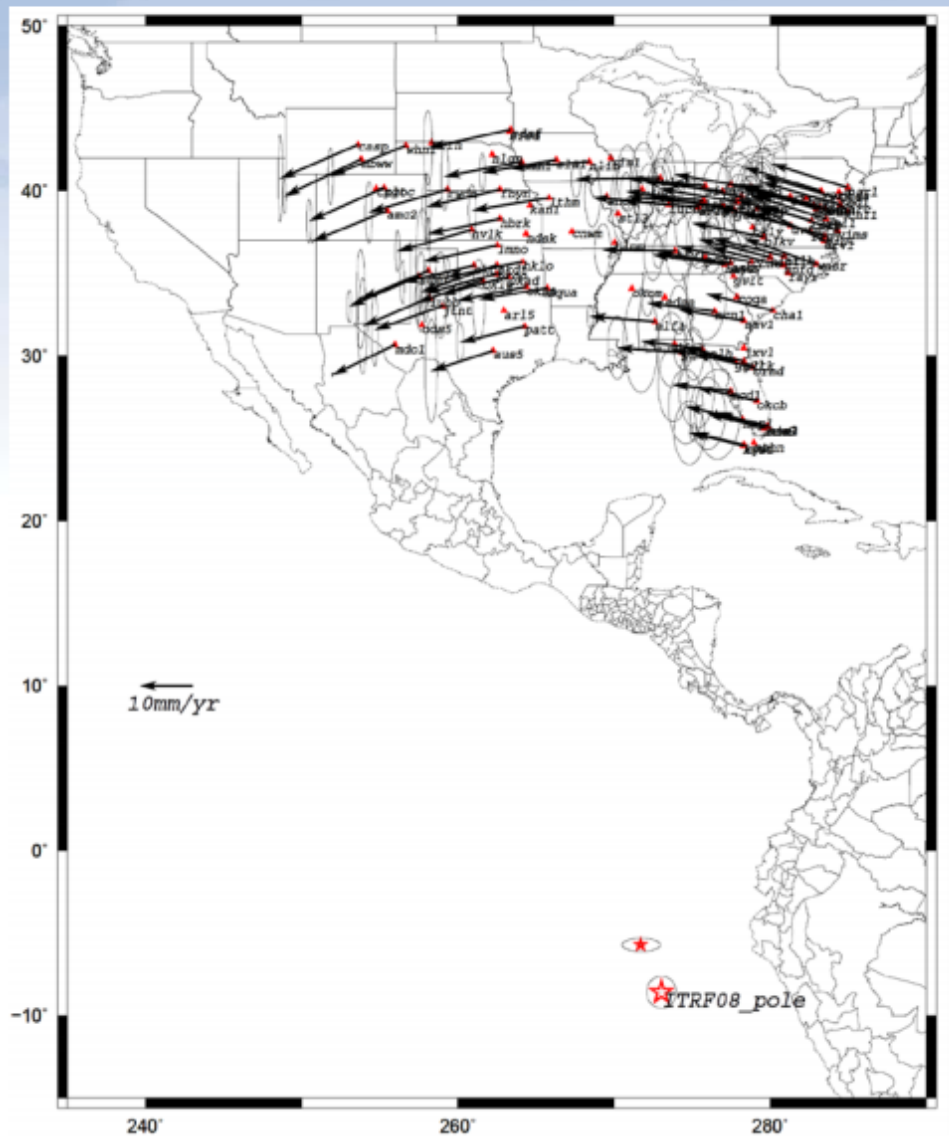
Euler Pole

Each reference frame will get:

- Euler Pole Latitude/Longitude
- Rotation rate (radians/year)

Used to compute time-dependent TRF2022 coordinates from time-dependent global (IGS) coordinates



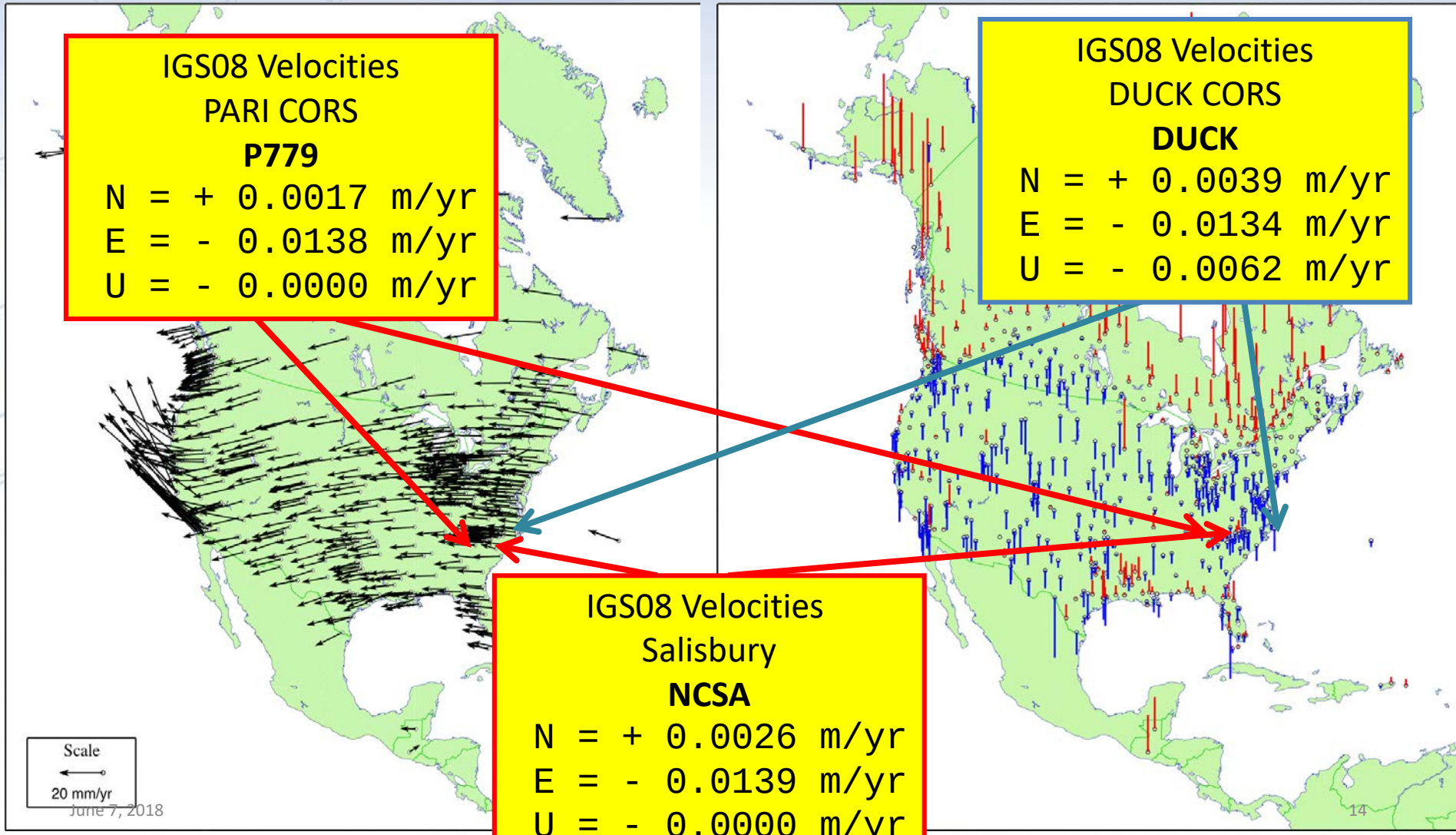


Euler's fixed point theorem states: any motion of a rigid body on the surface of a sphere may be represented as a rotation about an appropriately chosen rotation pole ("Euler Pole")

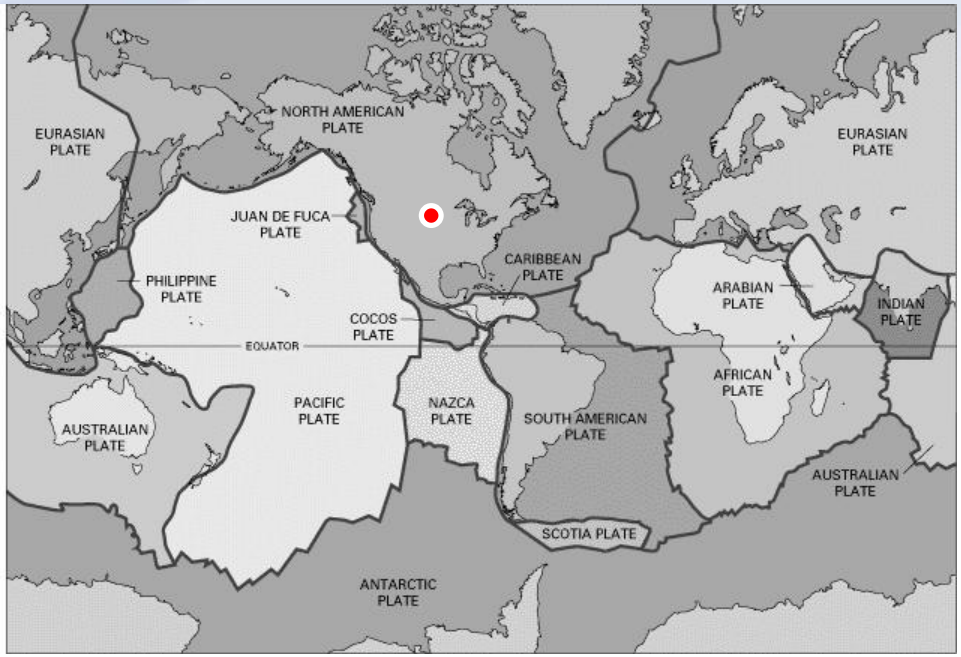
IGS08 Plate Velocities

Horizontal

Vertical



BSMK (North Dakota)



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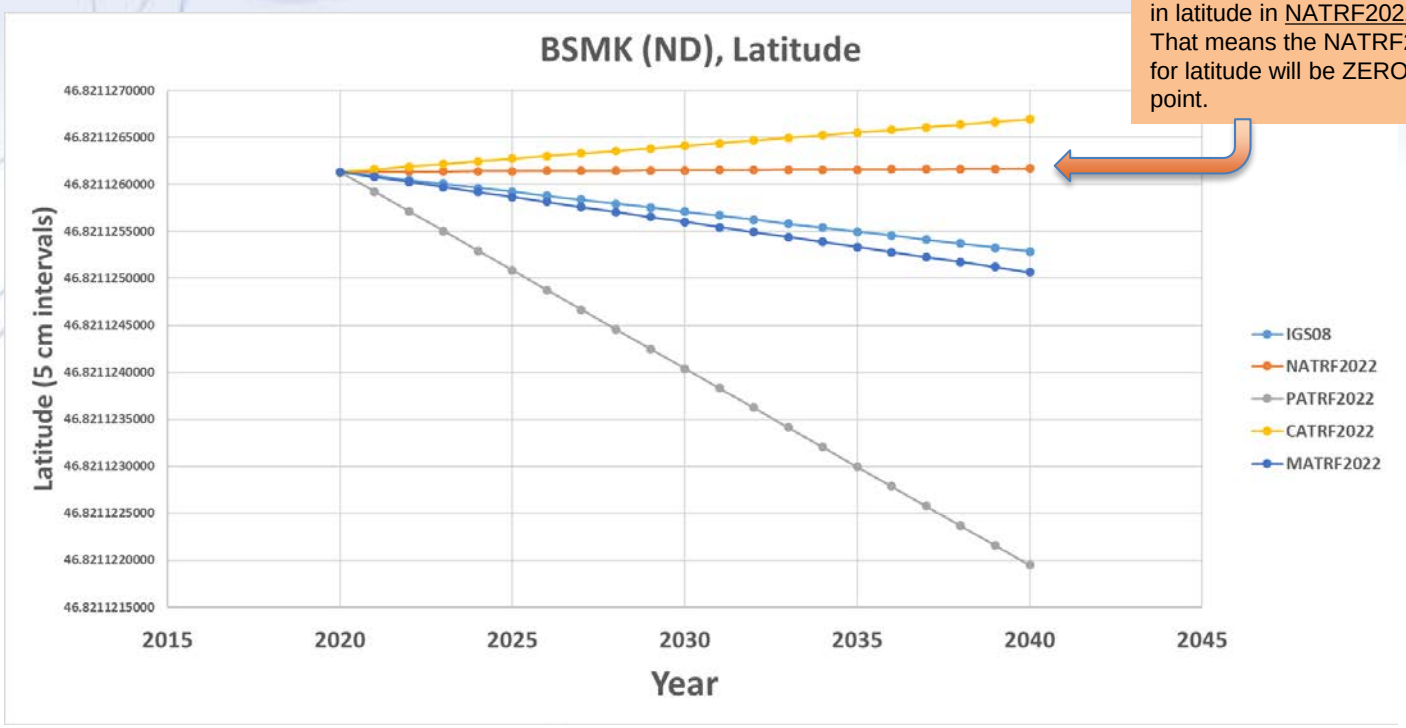
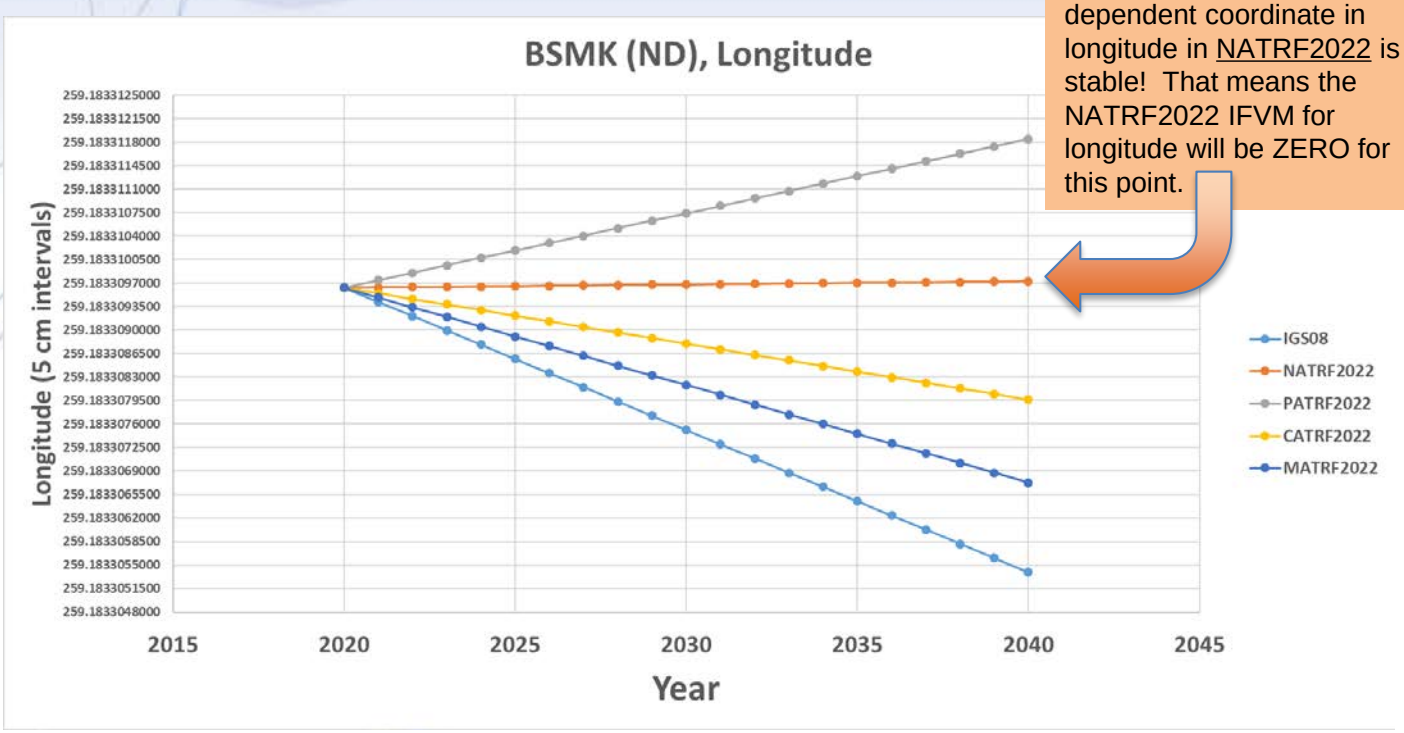


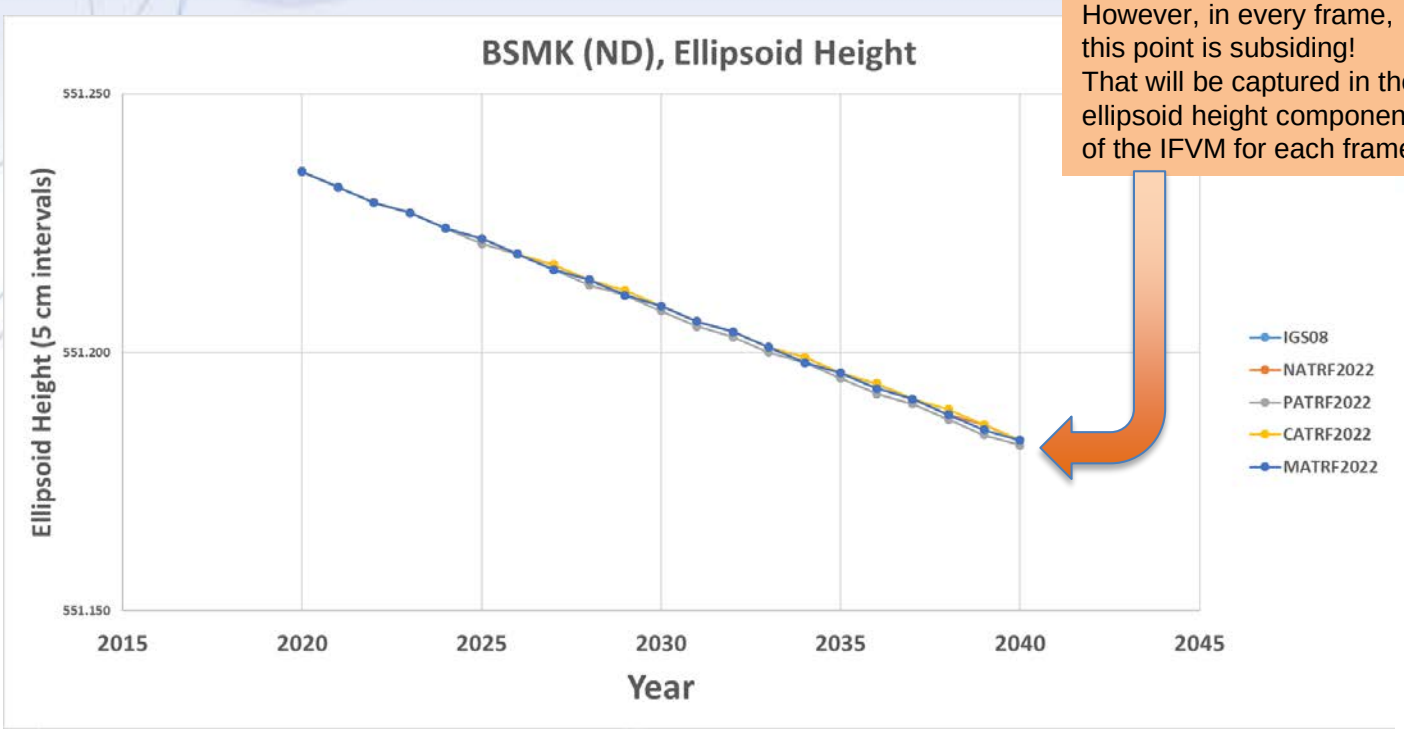
Note the time-dependent coordinate in latitude in NATRF2022 is stable! That means the NATRF2022 IFVM for latitude will be ZERO for this point.

BSMK (North Dakota)



Similarly, the time-dependent coordinate in longitude in NATRF2022 is stable! That means the NATRF2022 IFVM for longitude will be ZERO for this point.

BSMK (North Dakota)



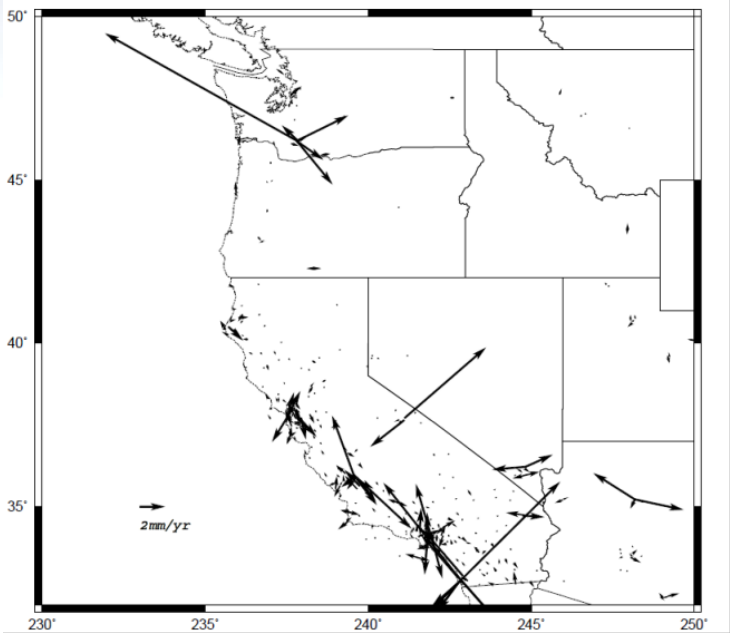
However, in every frame, this point is subsiding! That will be captured in the ellipsoid height component of the IFVM for each frame.

So…4 IFVMs?

- Yes. An IFVM for each frame.
- But here's the trick: The same exact data will go into creating all 4 of them.
  - It's just that each one will be relative to the Euler Pole rotation of a particular plate.

Can CORS alone serve as an IFVM?

- Eastern CONUS will largely be resolved
- Western CONUS has some anomalies



IFVM – How?

- Intra-Frame Velocity Models must:
  - Estimate non-Eulerian motions at any location
- Three primary methods being investigated
  - Interpolation from CORS
    - Pro: Easy
    - Con: Gets worse as CORS gets coarse
  - Satellite IfSAR
    - Pro: Covers vast areas
    - Con: No IfSAR experts in NGS; data availability issues
  - Geodynamic
    - Pro: Like HTDP, so NGS has experience
    - Con: Requires knowing *why* things move, rather than just measuring *that* they move (and requires "keeping up" with every event.)

Geoid18 (Hybrid model)

Geoid Quick Links

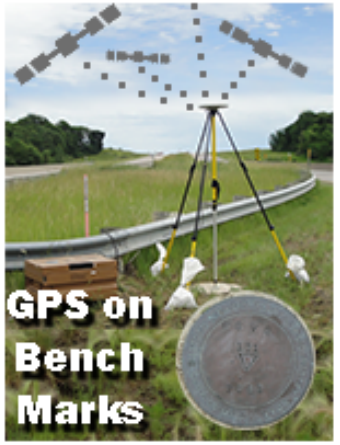
- NGS Geoid Home Page
- NGS Geoid models
- Publications
- NGS Geoid Research Page
- Geophysics of the Geoid
- Geoid Slope Validation Survey of 2011
- Geoid Slope Validation Survey of 2014
- xGEOID Model

Have a geoid question?

- Contact the Geoid Team

GEOID18

Hybrid Geoids convert NAD 83 ellipsoid heights to NAVD 88 orthometric heights. NGS will replace GEOID12B with GEOID18 in early 2019. This hybrid geoid model will provide improved GPS-derived NAVD 88 equivalent heights. It will be the last hybrid geoid model that NGS will create before NAVD 88 is replaced by the North American-Pacific Geopotential Datum of 2022 (NAPGD2022) in 2022.



Improvements through GPS on Bench Marks

To improve the accuracy and geographic coverage of GEOID18 and the transformation tool to transform data to NAPGD2022, users are encouraged to collect GPS data on leveled bench marks (GPS on BM) and submit the data to NGS via OPUS Share.

- A Prioritized list of marks for data collection are provided by NGS to help ensure that efforts are targeted toward areas where new data will make the most improvements. There are approximately 5700 benchmarks in this listing.
- Data must be received by August 2018 in order to be incorporated into the new model.
- You must submit at least 4 hours of data to OPUS to share. Each prioritized bench mark must have at least two separate GPS occupations.

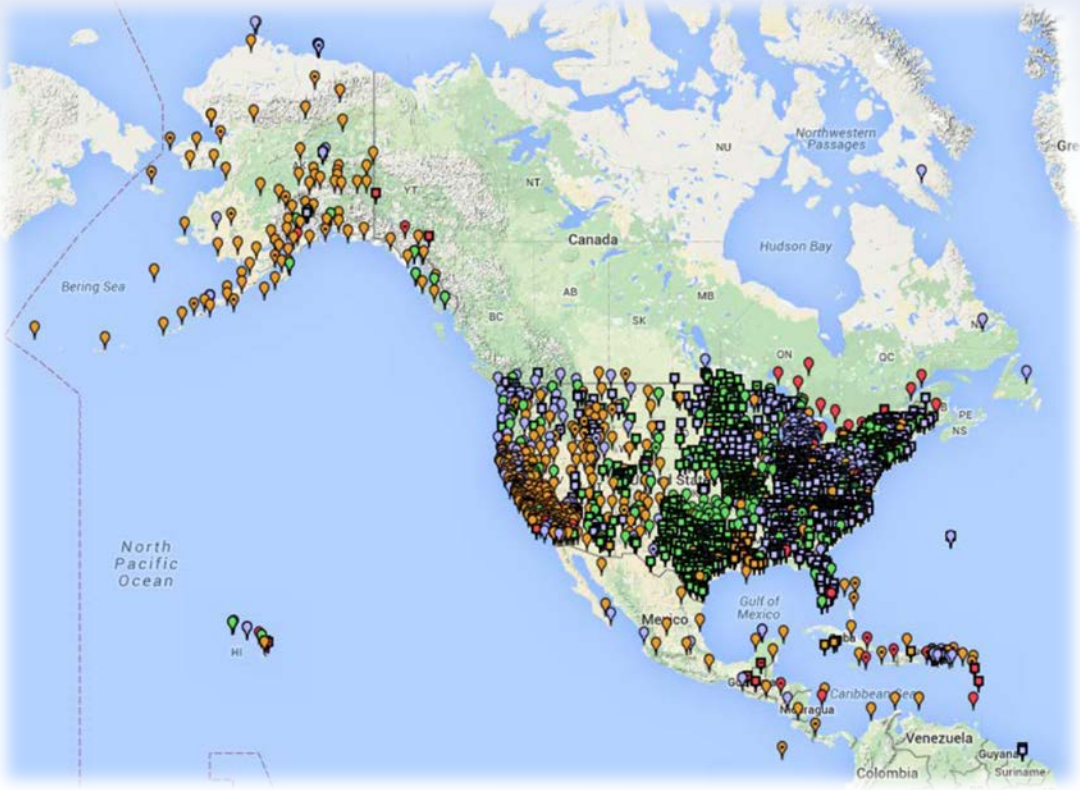
GPS on BM data submitted to improve GEOID18 will also be used to improve the 2022 Transformation Tool, which will be integrated into NCAT.

Website Owner: National Geodetic Survey / Last modified by **NGS Geoid Team** Mar 01 2018

Foundation CORS

Continuously Operating Reference Stations (CORS)

- ~1800 Continuously Operating Reference Stations
- Run by more than 200 organizations (various government, academic, and private organizations)
- Provide access to the U.S. National Spatial Reference System



Foundation CORS

Foundation CORS Requirements

Baseline Foundation CORS Network:

Collocate:
All sites within the Foundation CORS target area of the United States, with existing space geodetic techniques (SLR, VLBI or DORIS), will have a collocated Foundation CORS.

Additional Desired Foundation CORS Network Requirements:

- Density: Install or adopt new stations within the Foundation CORS target area of the United States. (Fulfill the spacing criteria of 800 kilometers within the Foundation CORS target area.)
- Plate Rotation (Euler Pole): Install or adopt new stations within the U.S. Foundation CORS target area to raise the minimum number of Foundation CORS to three on each of the four plates of interest, once the above criteria are met.
- Additional (Gap Filling): Install or adopt new stations, on a case-by-case basis, once the above criteria is met (*).

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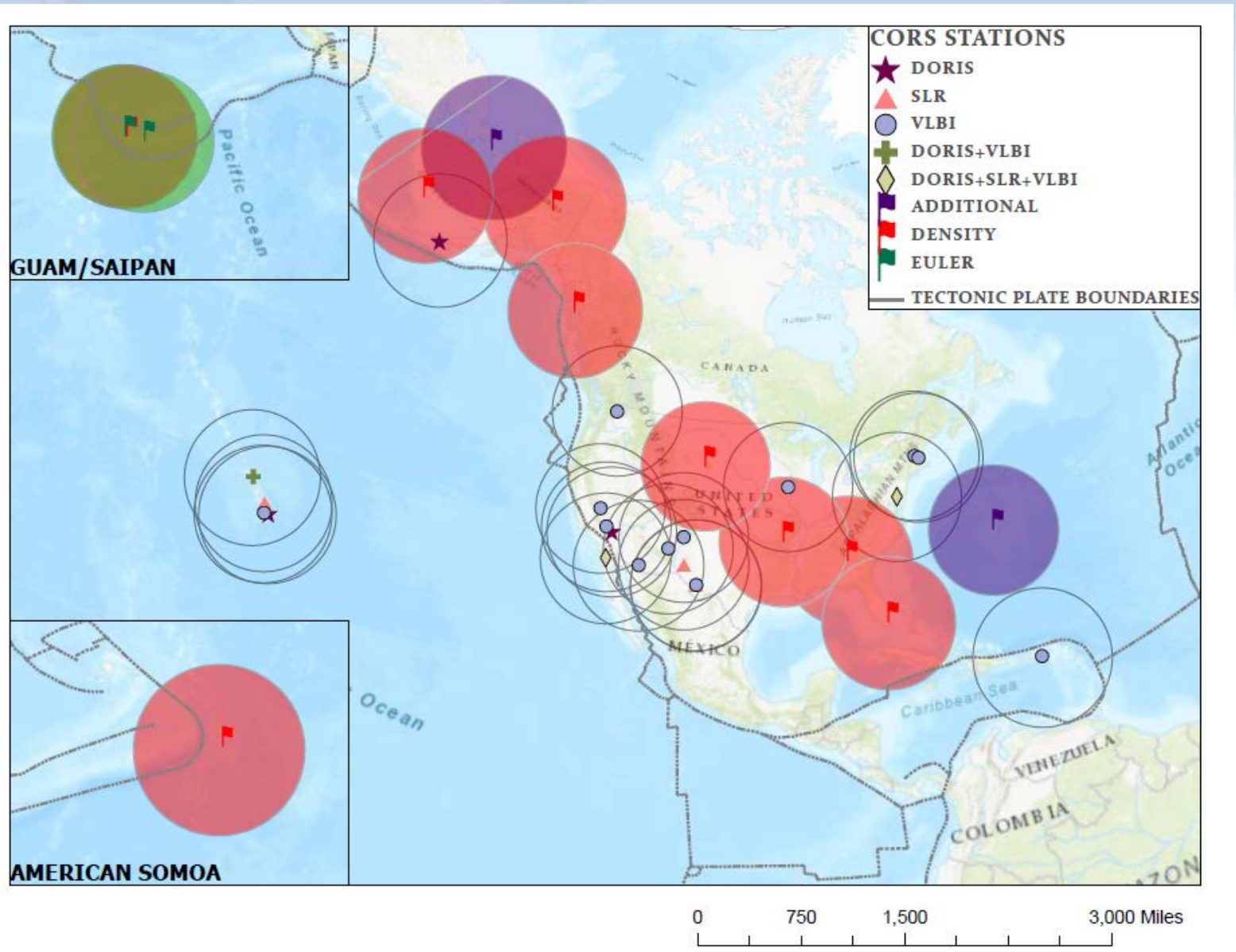
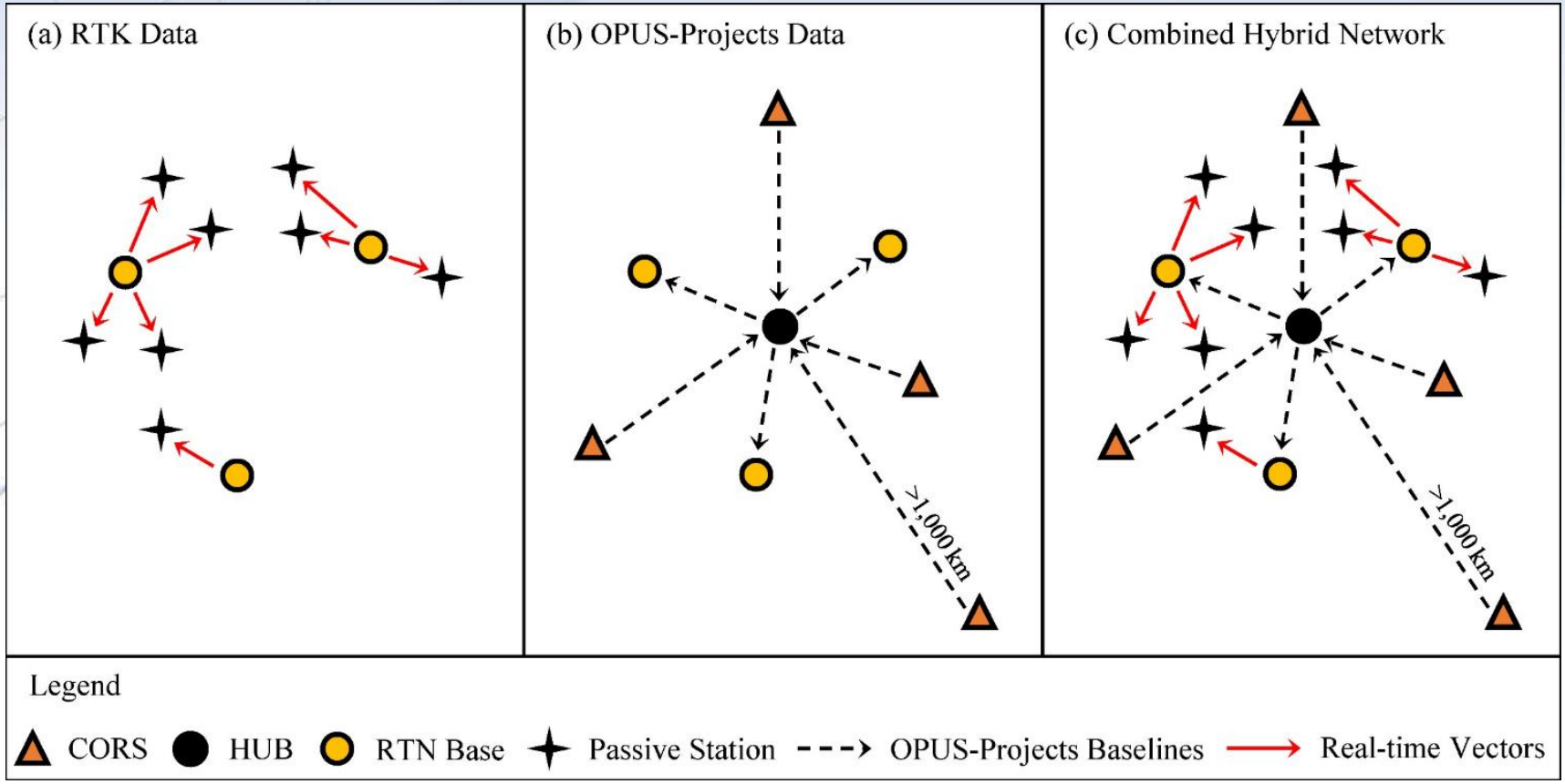
Collocated + Density + Plate Rotation + Additional



Potentially adding RTK vectors to OPUSprojects

Hybrid Static + RTN Survey Networks

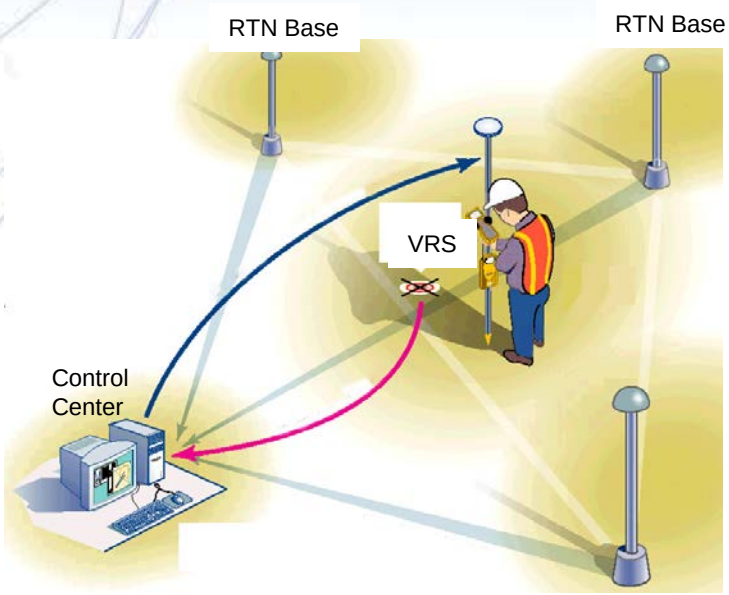


[Weaver et al. 2018]

Methods for Receiving Corrections from an RTN

Virtual Reference Station (VRS)

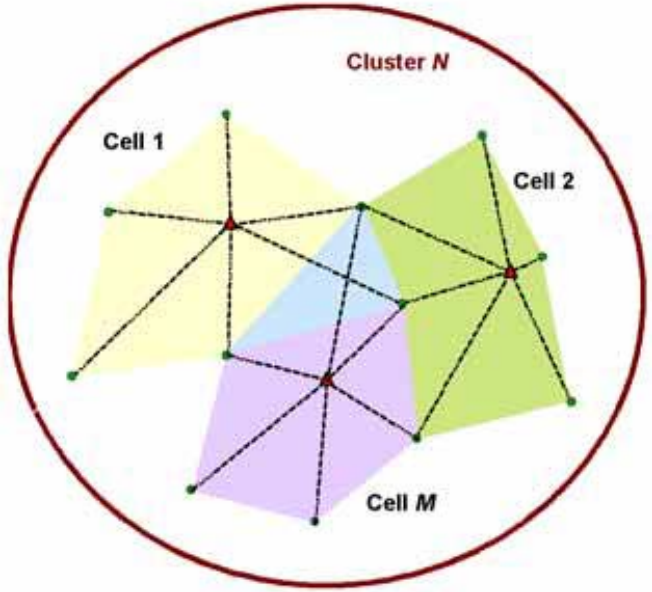
- Vector "tails" referenced to virtual base station—can be moved to physical ref. station (PRS)



(Landau et al. 2002)

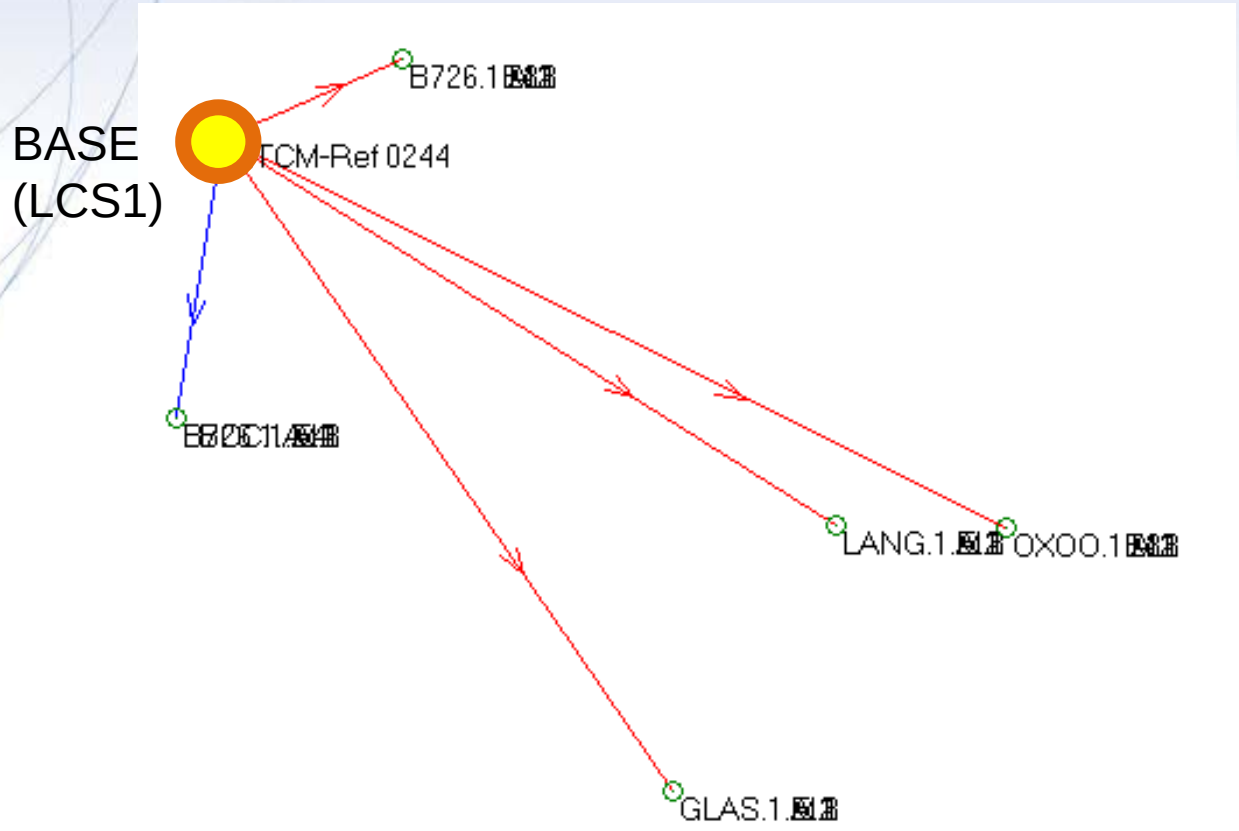
Master-Auxiliary Concept (MAC)

- Vector "tails" connected to physical base station
- Base station position is fixed

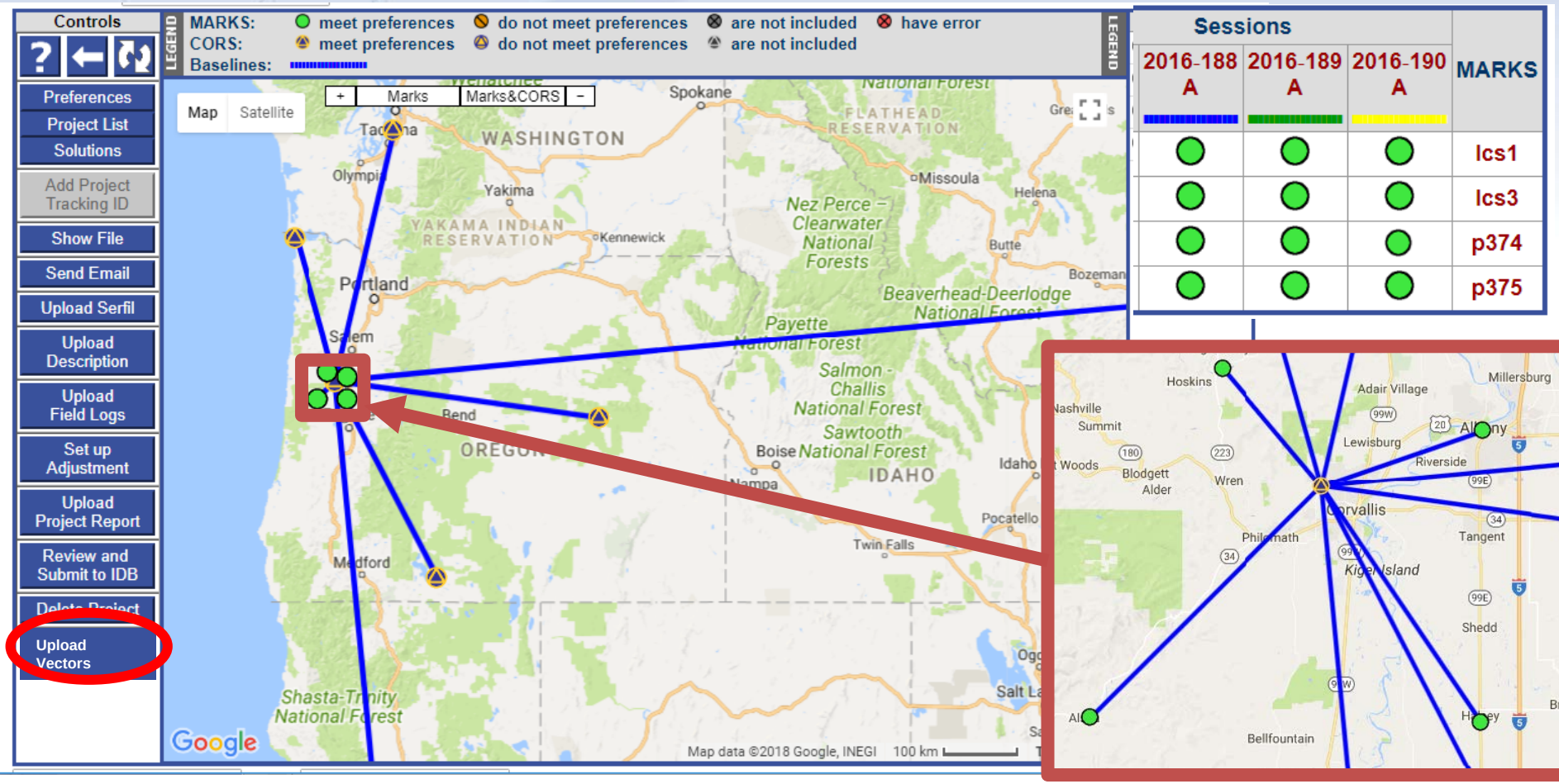


(Leica 2005)

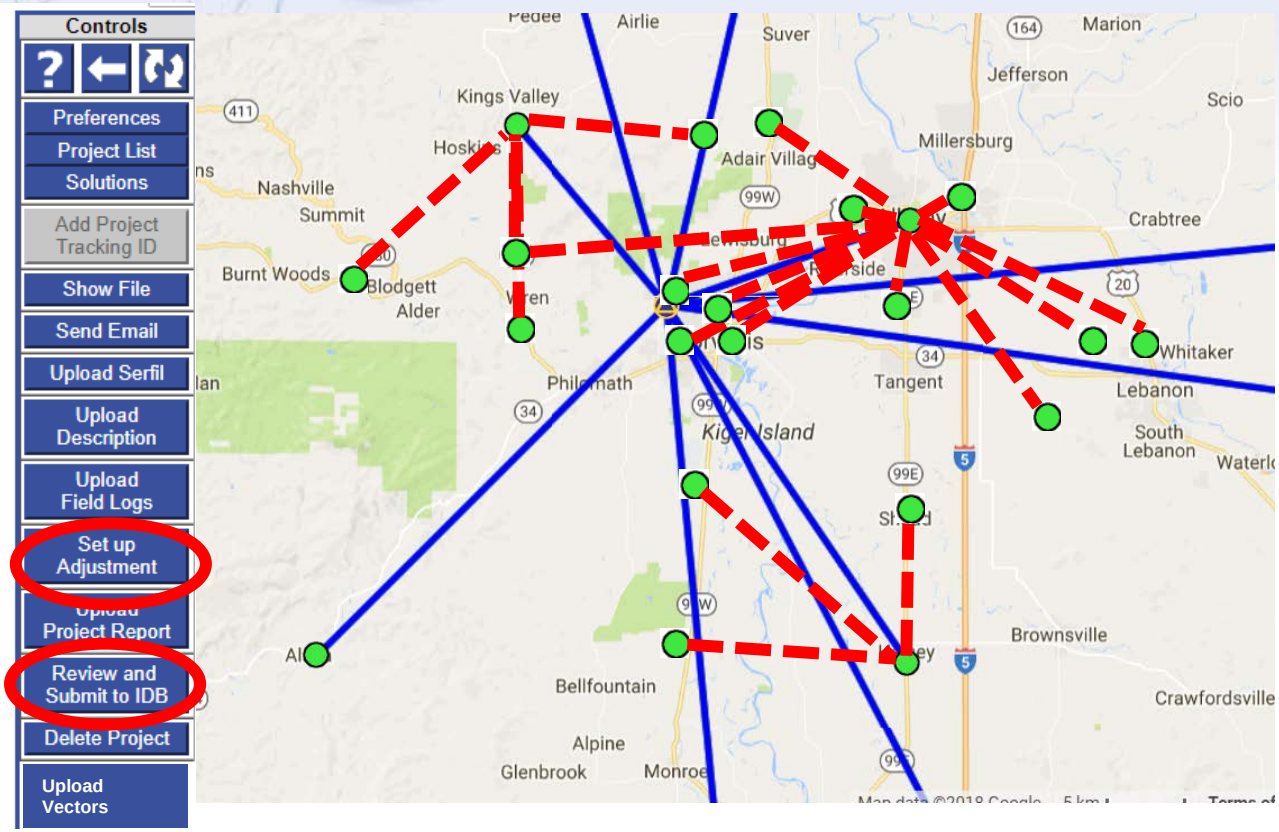
Example: Download RTN Data



Example: Process Static Data in OPUS-Projects



Example: Upload RTN Vectors to OPUS-Projects



Example: Adjust Static + RTN Network

- Run least squares adjustment(s) of the combined static data and RTN vectors in the survey network
- Hold CORS (and possibly other published coordinates on passive marks) as control in network adjustments
- Check quality of results
- Submit survey project to NGS for review and publication in national database

Questions?