Dynamic Geometric Reference Frames

NGS crustal motion models

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"Shift & Drift"

- Sudden ***SHIFT***. For CONUS at epoch 2020.0 for change from NAD 83:
  - Horizontal change of about **0.8 to 3 meters**
  - Ellipsoid height change of about **-0.1 to -1.6 meters**
- Continuous ***DRIFT*** due to crustal motion
  - Average about **2 cm/yr** in CONUS (horizontal)
  - Can remove most by modeling tectonic plate (***horizontal only***)
  - Remaining 3D motion minimized with **crustal motion models**
- **Crustal motion models**
  - ***Current NSRS:*** **HTDP (Horizontal Time-Dependent Positioning)**
  - ***Modernized NSRS:*** **IFDM2022 (Intra-Frame Deformation Model of 2022)**

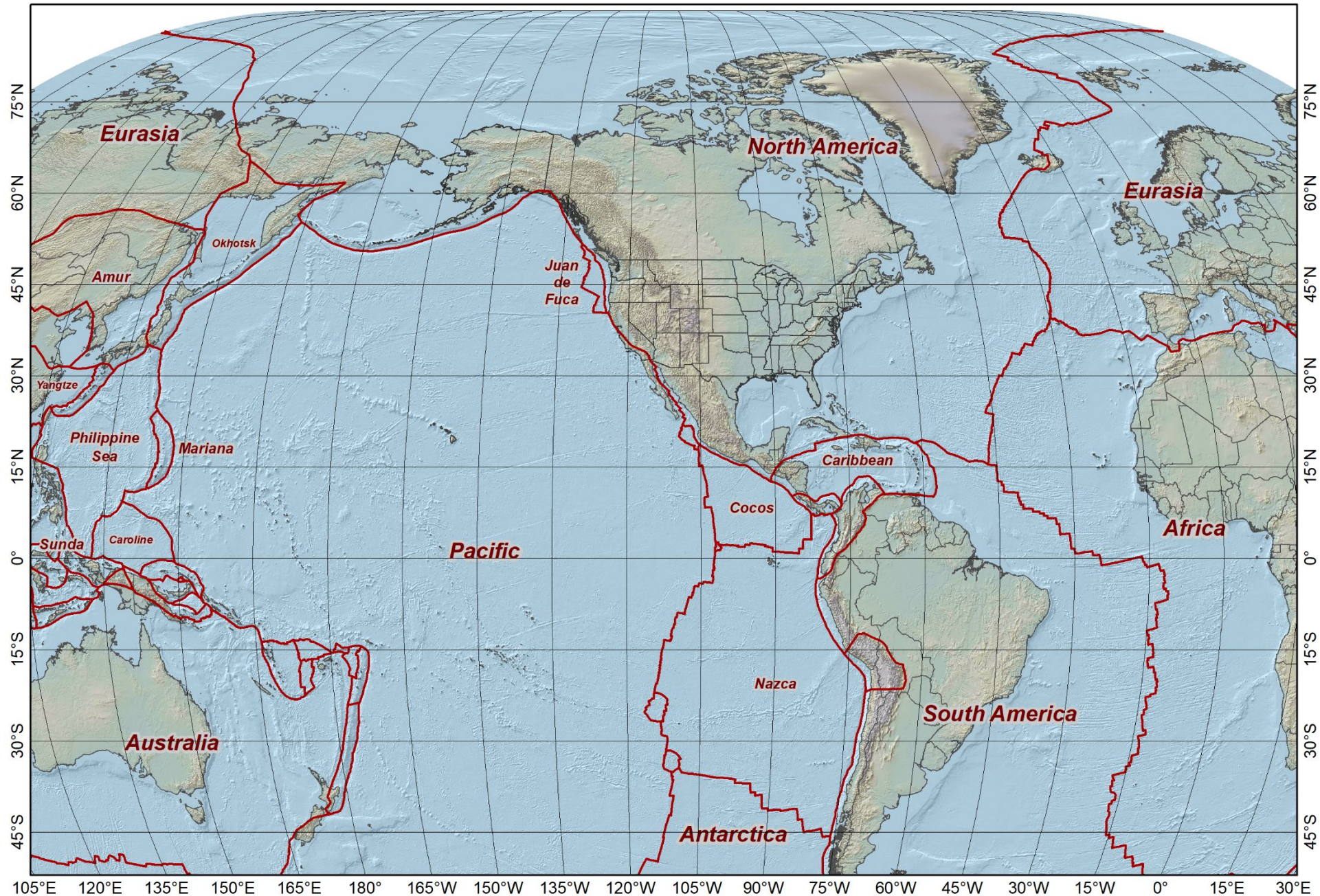
HTDP: Horizontal Time-Dependent Positioning

- **Currently used by NGS to transform across space and time**
- **Uses two overall transformation methods:**
  - 14-parameter Helmert transformations
  - Crustal motion models
    - Constant-velocity grids (***horizontal only***)
    - Coseismic dislocation models (generally have vertical component)
    - Postseismic earthquake grid (one in Alaska), also with vertical component
    - Plate rotation models for entire Earth (only used where there are no velocity grids)
- **All crustal motion models built into executable itself**
  - Source code in five Fortran files

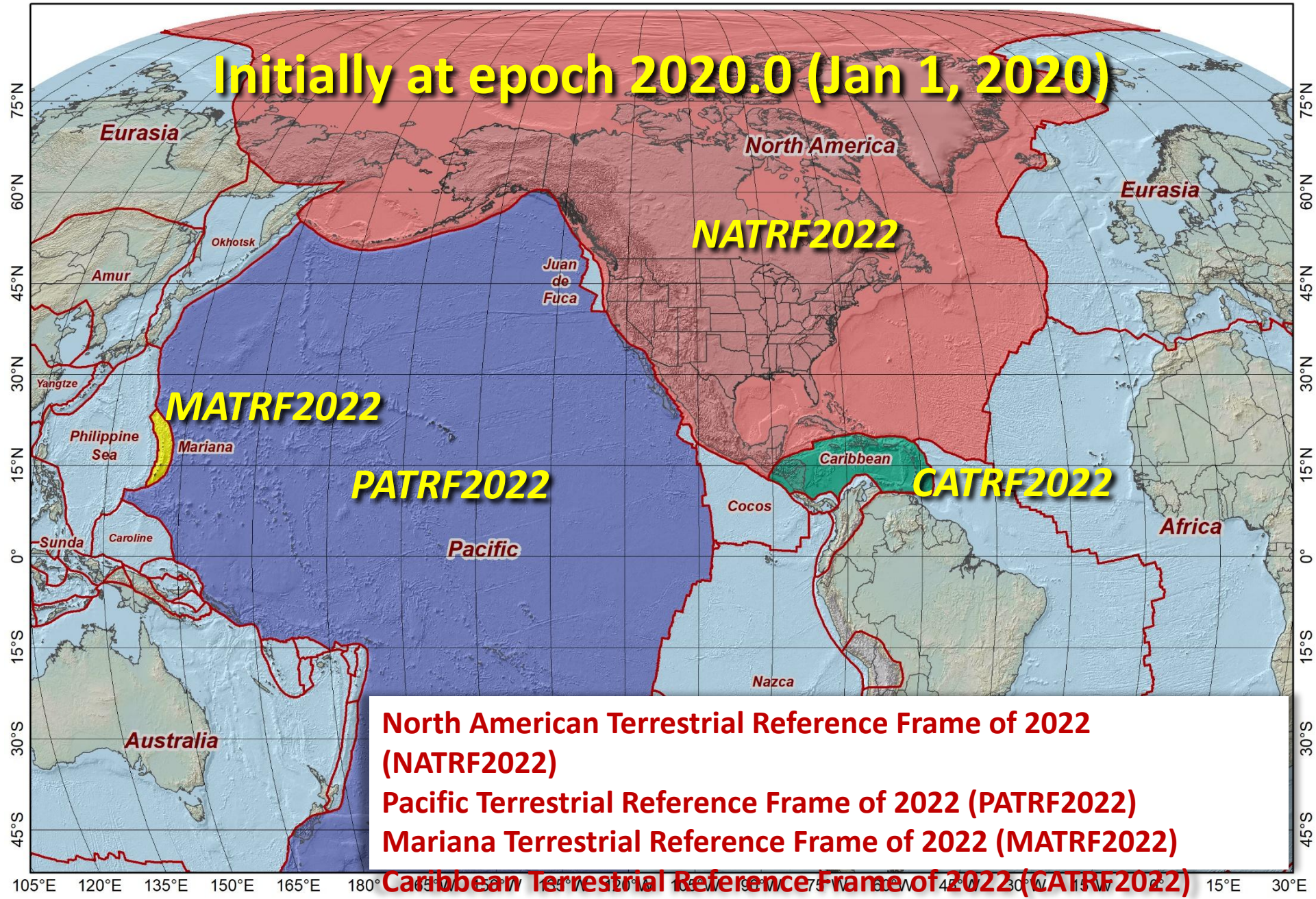
IFDM2022: Intra-Frame Deformation Model

- **"IFDM2022" name associated with NSRS modernization**
  - Initially released as version 1.0
  - Later version 2.x may be substantially different
- **IFDM2022 v1.0 based (in part) on TRANS4D**
  - TRANS4D velocity grids (external to executable)
  - Higher resolution with vertical component
  - Includes velocity uncertainty estimates
  - Same earthquake models as HTDP
- **Plan update of HTDP before NSRS modernization**
  - Keep "HTDP" name but use TRANS4D grids
  - Will not include uncertainty estimates in output

Tectonic plates



Tectonic plates “fixed” for the four 2022 Terrestrial Reference Frames



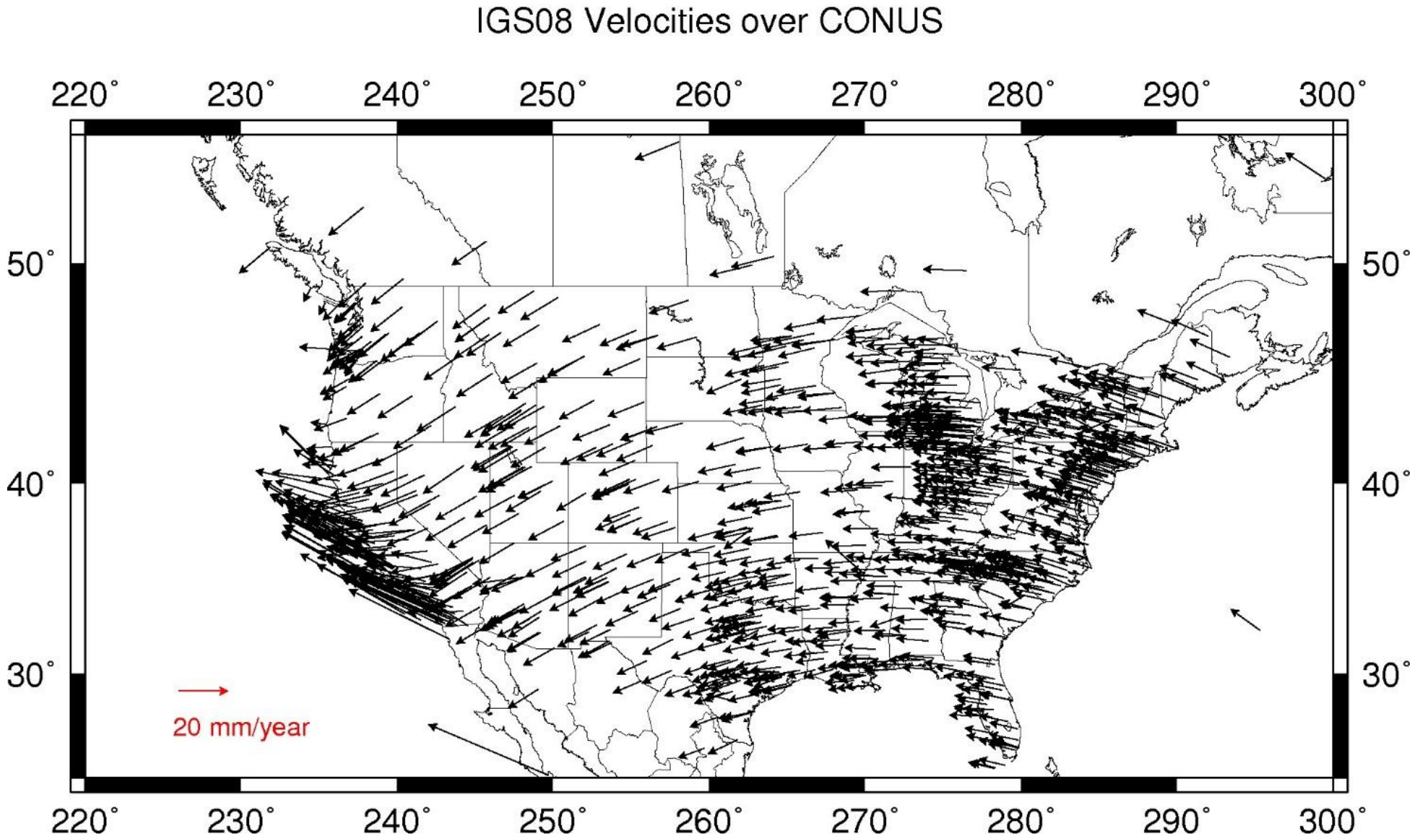
North American Terrestrial Reference Frame of 2022 (NATRF2022)

Pacific Terrestrial Reference Frame of 2022 (PATRF2022)

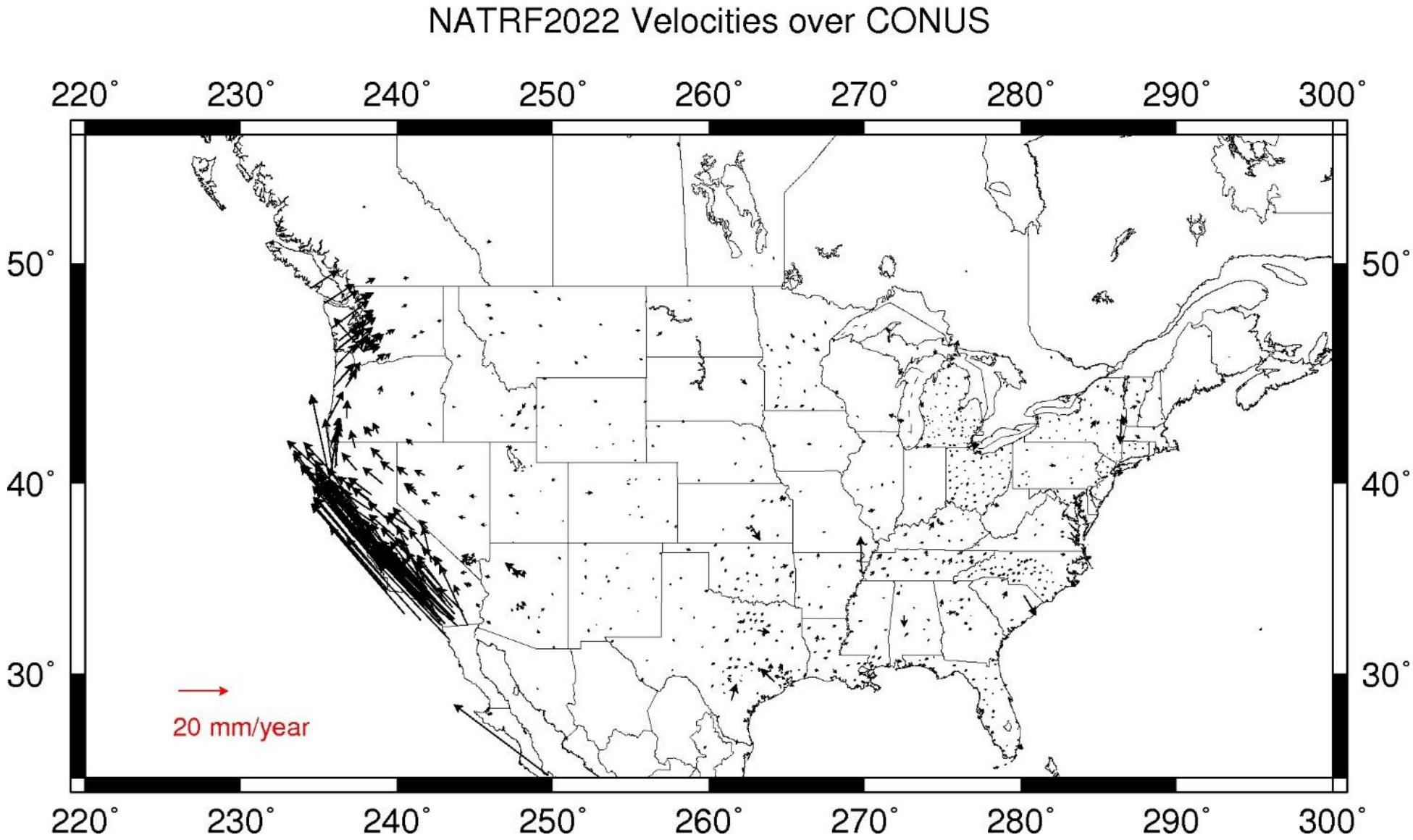
Mariana Terrestrial Reference Frame of 2022 (MATRF2022)

Caribbean Terrestrial Reference Frame of 2022 (CATRF2022)

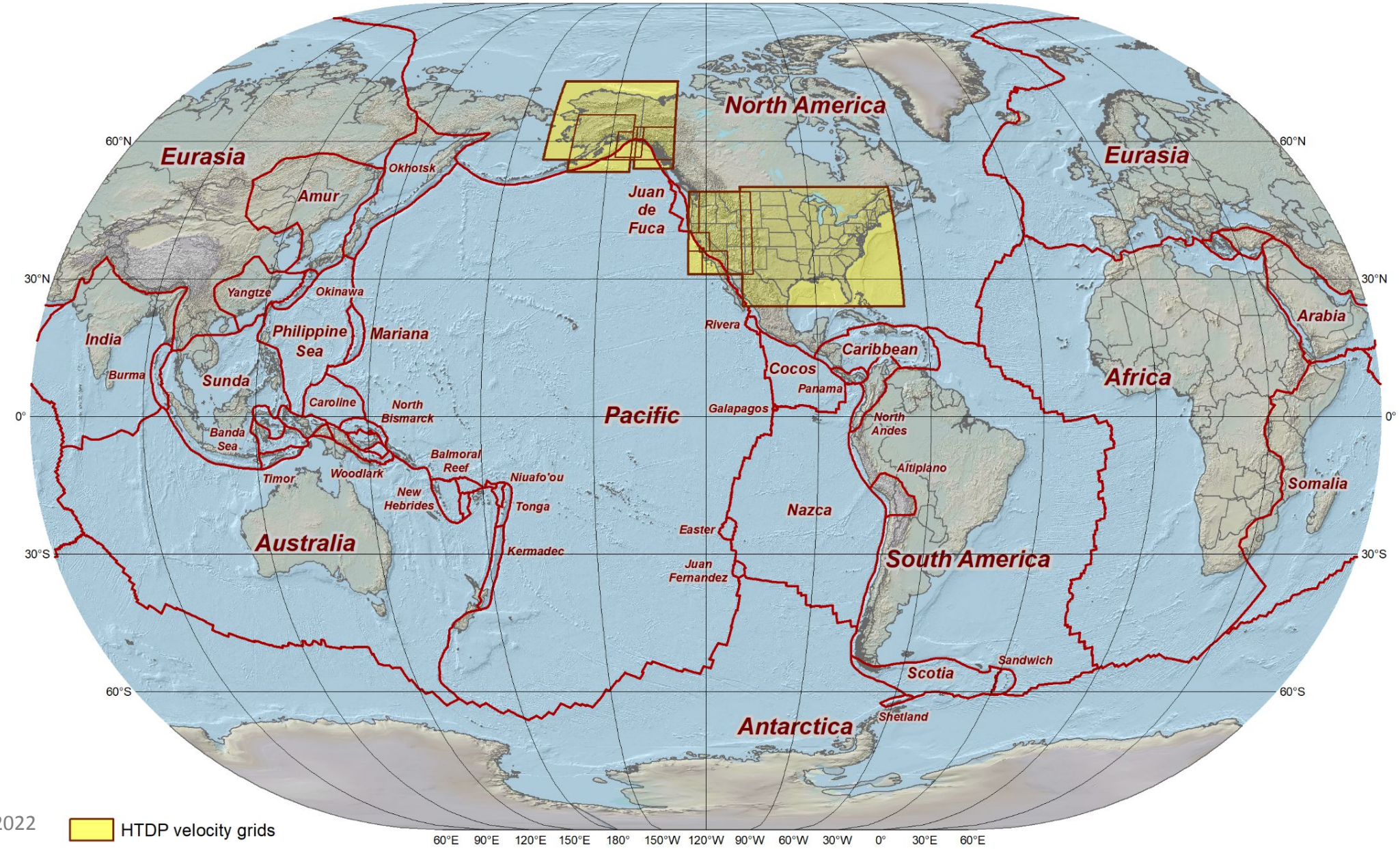
IFDM velocities with respect to ITRF2020



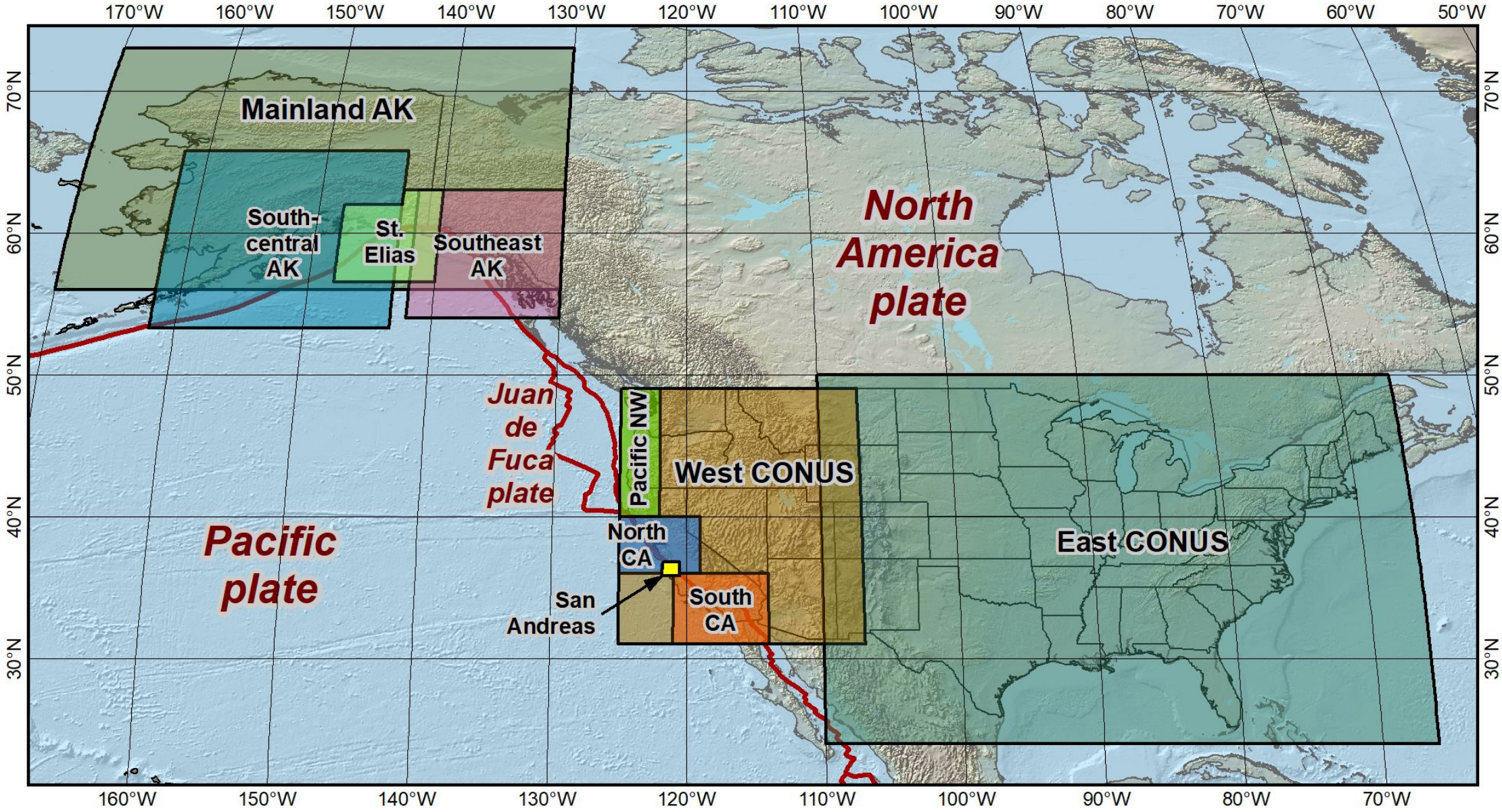
IFDM velocities with respect to NATRF2022



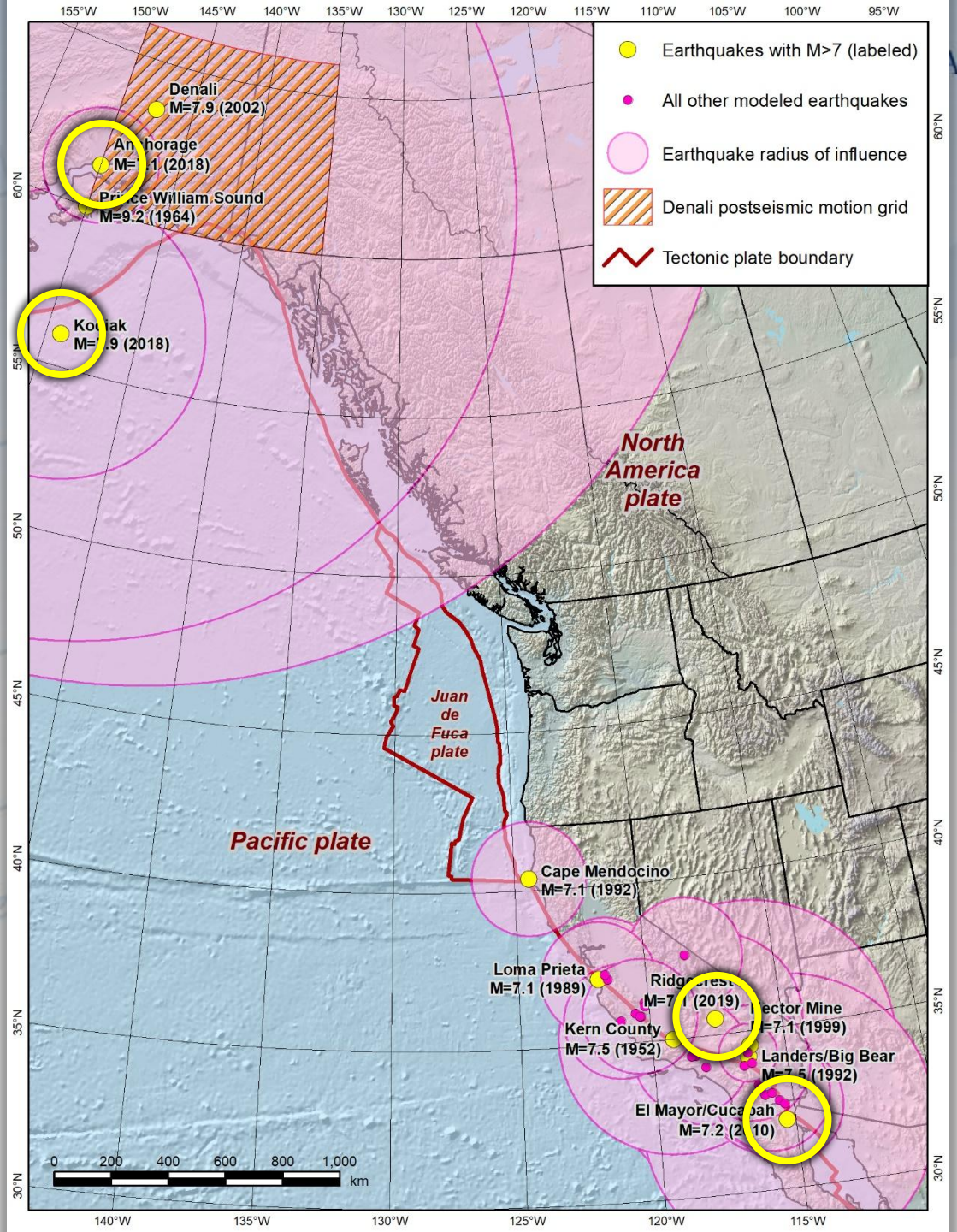
Tectonic plates and velocity grids in HTDP v3.5.0



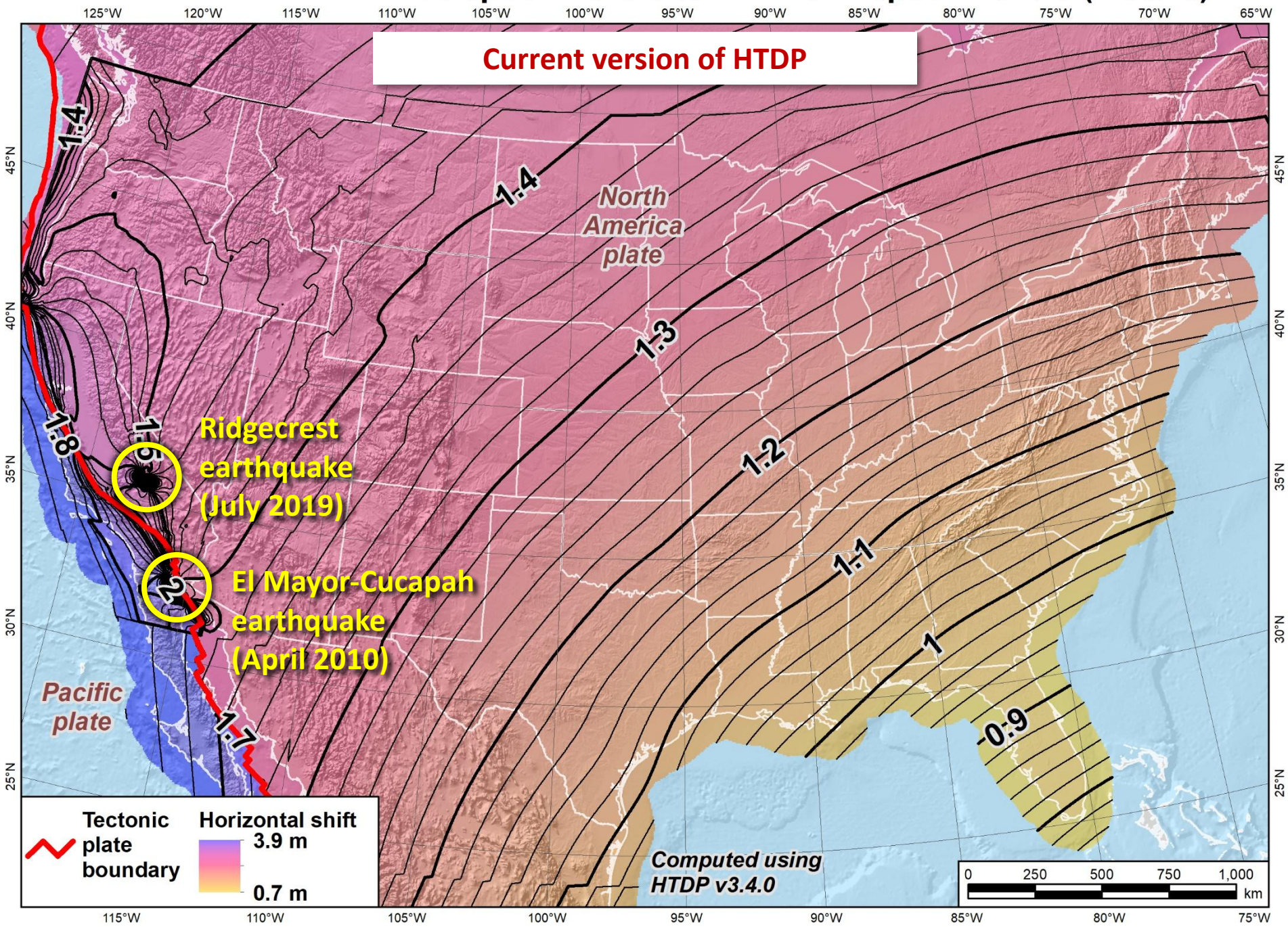
Velocity grids in HTDP v3.5.0

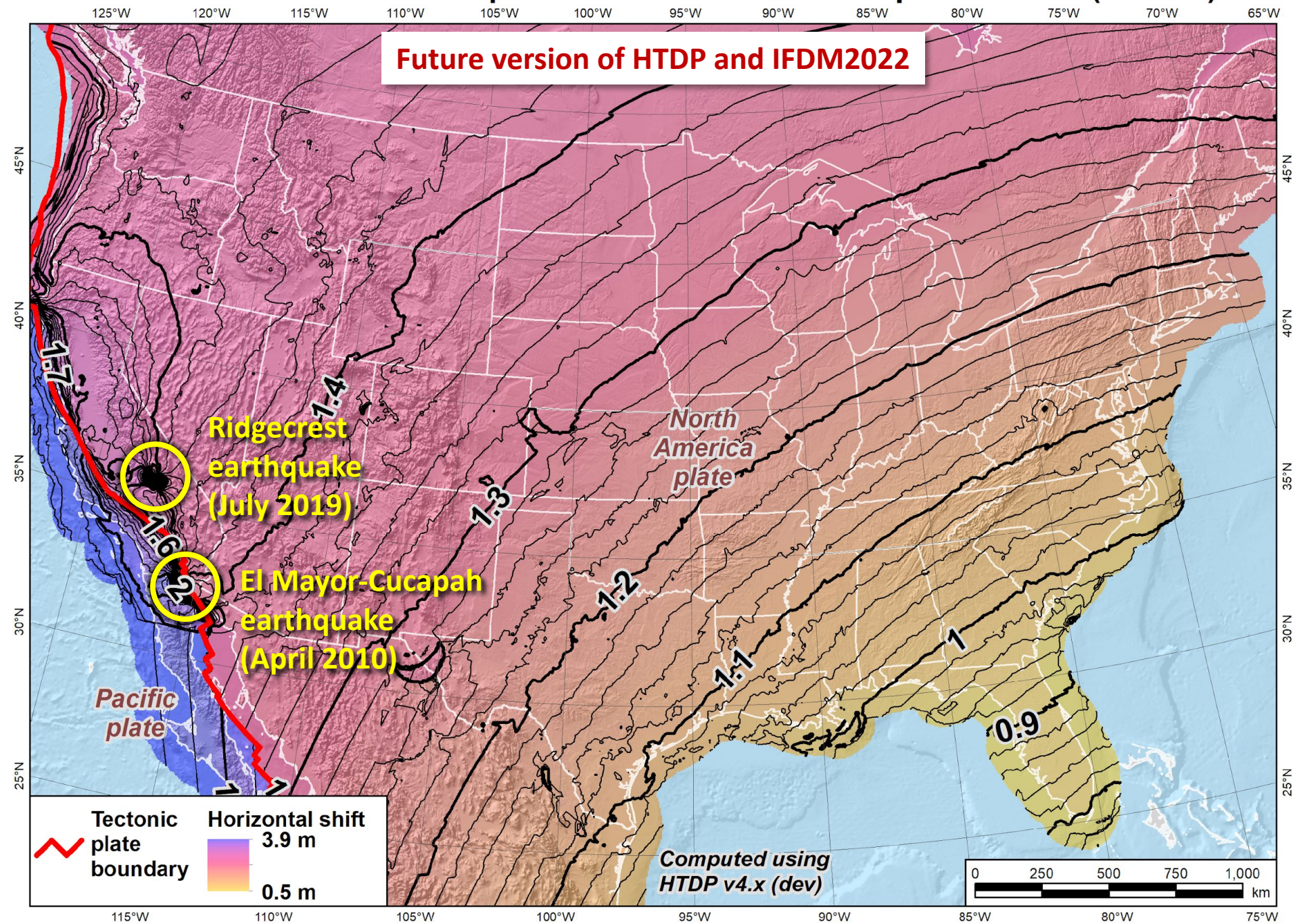


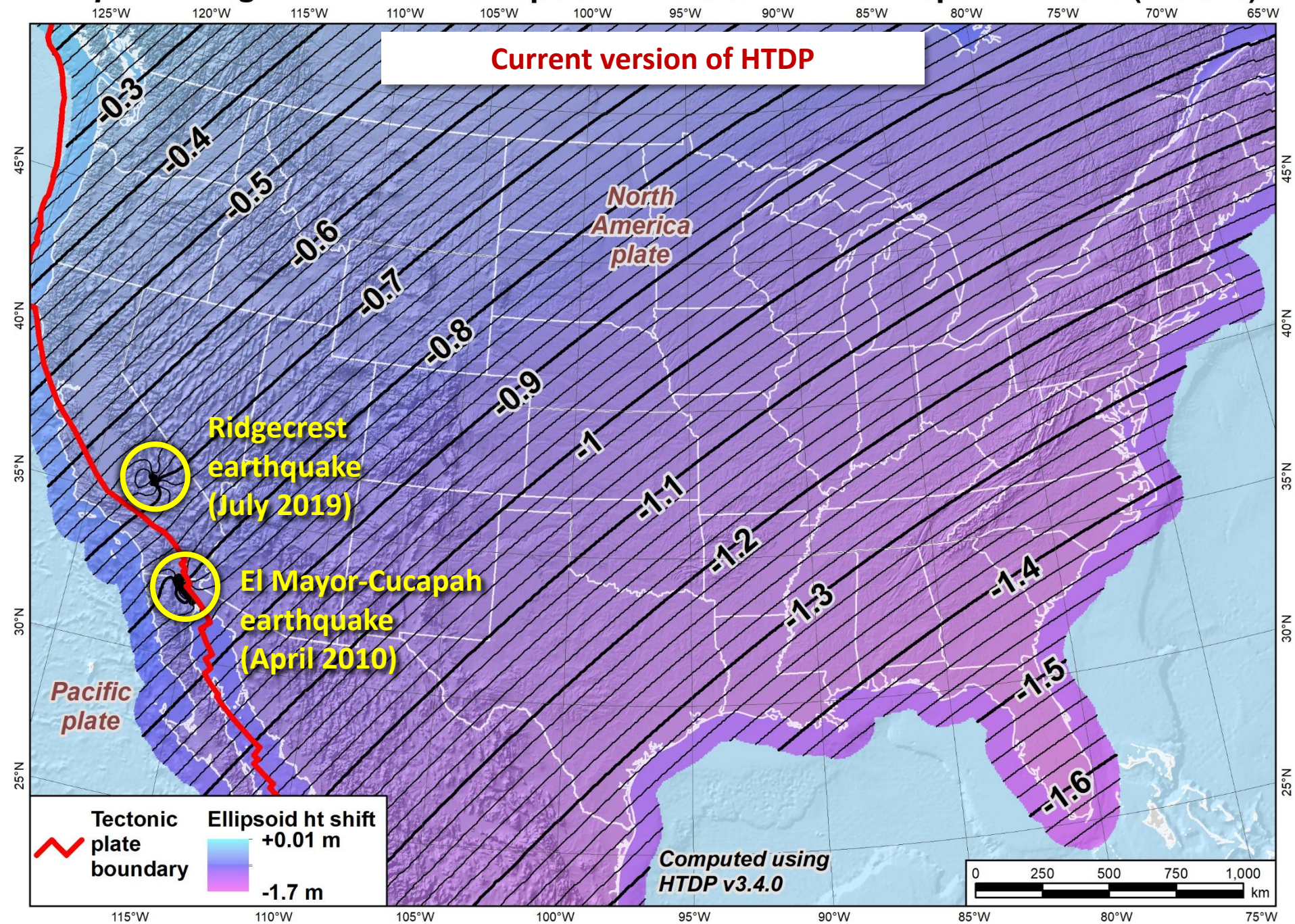
Earthquake models in HTDP v3.5.0 (and TRANS4D)

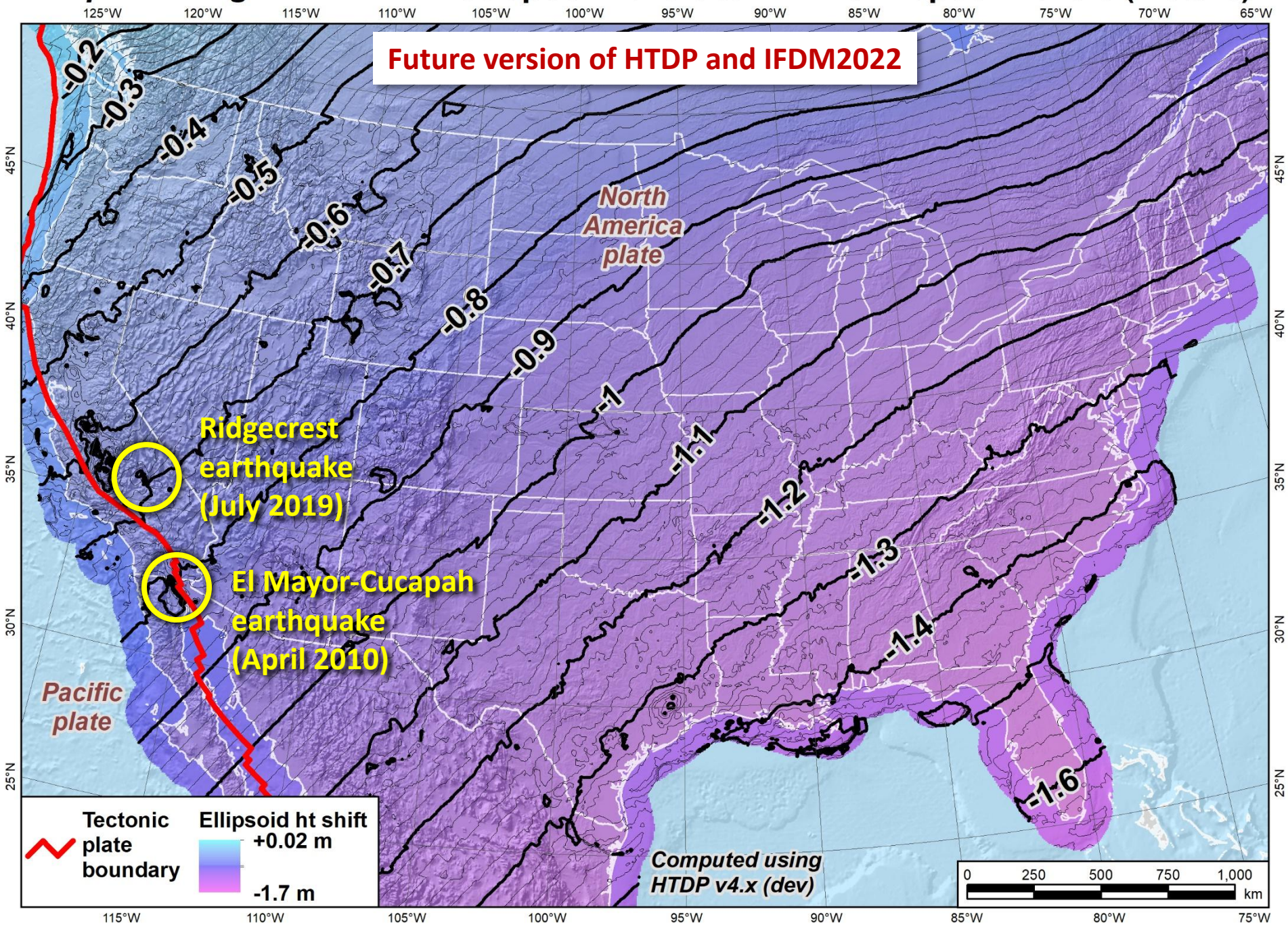


- **Coseismic models**
  - Okada dislocation models (***not*** grids)
  - Fault rupture surface modeled
  - 32 models (1934 – 2019)
- **Postseismic grid**
  - One in Alaska (2002 Denali earthquake)
  - Time decay (motion decreases with time)
- **Models included in executable**
- **Problems:**
  - Long time lag for model development
  - Models created outside NGS
  - Often multiple models but must choose one


Horizontal shift: NAD83 epoch 2010.0 to ITRF2014 epoch 2020.0 (meters)
Current version of HTDP
North America plate
Pacific plate
Ridgecrest earthquake (July 2019)
El Mayor-Cucapah earthquake (April 2010)
1.4
1.3
1.2
1.1
1
0.9
1.8
1.5
2
1.7
Tectonic plate boundary
Horizontal shift
3.9 m
0.7 m
Computed using HTDP v3.4.0
0 250 500 750 1,000 km
125°W 120°W 115°W 110°W 105°W 100°W 95°W 90°W 85°W 80°W 75°W 70°W 65°W
45°N 40°N 35°N 30°N 25°N


Horizontal shift: NAD83 epoch 2010.0 to ITRF2014 epoch 2020.0 (meters)
Future version of HTDP and IFDM2022
Ridgecrest earthquake (July 2019)
El Mayor-Cucapah earthquake (April 2010)
North America plate
Pacific plate
Tectonic plate boundary
Horizontal shift
3.9 m
0.5 m
Computed using HTDP v4.x (dev)
0 250 500 750 1,000 km


Ellipsoid height shift: NAD83 epoch 2010.0 to ITRF2014 epoch 2020.0 (meters)
Current version of HTDP
125°W 120°W 115°W 110°W 105°W 100°W 95°W 90°W 85°W 80°W 75°W 70°W 65°W
45°N 40°N 35°N 30°N 25°N
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
-1.2
-1.3
-1.4
-1.5
-1.6
North America plate
Pacific plate
Ridgecrest earthquake (July 2019)
El Mayor-Cucapah earthquake (April 2010)
Tectonic plate boundary
Ellipsoid ht shift
+0.01 m
-1.7 m
Computed using HTDP v3.4.0
0 250 500 750 1,000
km


Ellipsoid height shift: NAD83 epoch 2010.0 to ITRF2014 epoch 2020.0 (meters)
Future version of HTDP and IFDM2022
North America plate
Pacific plate
Ridgecrest earthquake (July 2019)
El Mayor-Cucapah earthquake (April 2010)
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
-1.1
-1.2
-1.3
-1.4
-1.6
Tectonic plate boundary
Ellipsoid ht shift
+0.02 m
-1.7 m
Computed using HTDP v4.x (dev)
0 250 500 750 1,000 km
125°W 120°W 115°W 110°W 105°W 100°W 95°W 90°W 85°W 80°W 75°W 70°W 65°W
45°N 40°N 35°N 30°N 25°N

IFDM for NSRS Modernization

- Will use modern Open Geospatial Consortium (OGC) standards
  - **Geodetic Grid Exchange Format (GGXF)** for grid formats
  - **Deformation Model Functional Model (DMFM)**, including coseismic events
- Latitude/longitude grids in ITRF2020
- Will give same results as NADCON at reference epochs
  - Interval of 5 or 10 years (TBD)
  - First is epoch 2020.0, second will be 2025.0 (or 2030.0), etc.
  - Like NADCON, should not be interpreted as geodetic-quality
- Coordinate with Canada to ensure consistent results across border

IFDM implementation for modernized NSRS

- Expected coverage areas for IFDM2022 in modernized NSRS

Region	North	South	West	East
CONUS	50°	24°	235°	294°
Alaska	73°	50°	172°	232°
Hawaii	23°	18°	199°	206°
PR/VI	19°	17°	291°	296°
Guam/CNMI	22°	12°	143°	147°
Am. Samoa	-13°	-16°	188°	193°

- Initial internal development using existing NGS formats in Fortran
- Alpha version based on GGXF and DMFM release date TBD