Automatic Segmentation of Geophysical Trackline Data Applied to Pacific-Rivera Motion

Daniel Woodworth[1] and Kevin Gaastra[1]

[1]Rice University

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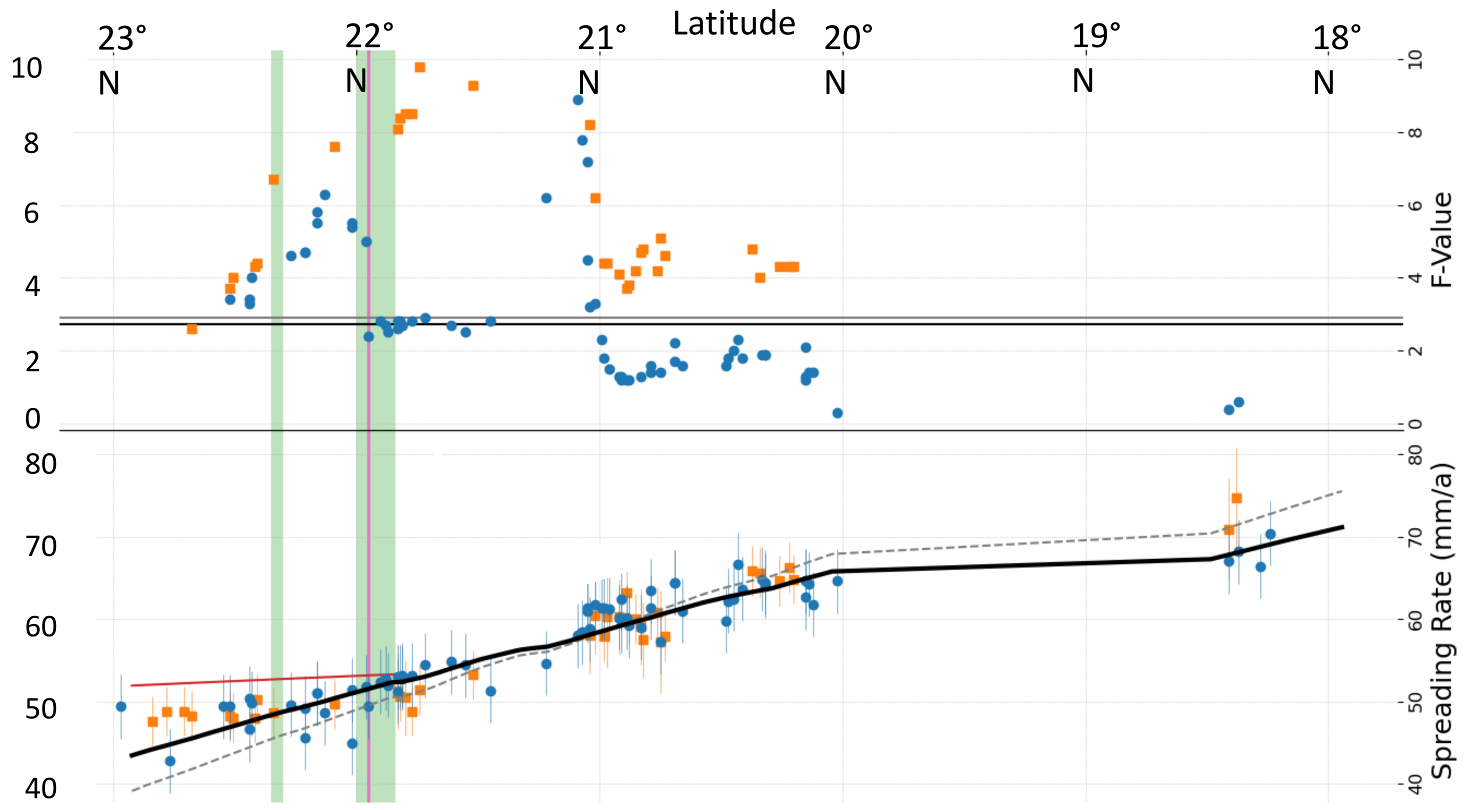
Abstract

Magnetic trackline data are of central importance in estimating relative plate motions, have allowed a detailed apparent polar wander path to be determined for the Pacific Plate from skewness analysis, and provide important constraints for many other geophysical investigations. Interpreting trackline data typically requires processing, which often involves dividing tracks into quasi-linear segments. Here we present a method for automating this processing step by adapting the Ramer-Douglas-Peucker (RDP) algorithm, originally developed for polygonal approximation and cartographic generalization, for use on trackline data on a sphere and demonstrate its ability to segment data into quasi-linear (i.e., great circle-like) sections quickly based on two intuitive parameters. The new procedure is largely automated and requires minimal effort. As a test and proof of concept, we apply this method to estimate an angular velocity for motion between the Pacific and Rivera plates since 0.781 Ma using data from the NCEI geophysical trackline database. Our modified RDP algorithm identified 400+ track segments that intersected the Rivera Rise, of which more than 50 provided useful Pacific-Rivera spreading rates, which is roughly twice the 26 rates used to estimate Pacific-Rivera motion in the MORVEL set of geologically current plate relative angular . We compare the resulting angular velocity to previous estimates of Pacific-Rivera angular velocity and explore implications for Pacific-North America and Pacific-Cocos relative motion and Rivera absolute motion.

Automatic Segmentation of Geophysical Trackline Data Applied to Pacific-Rivera Motion

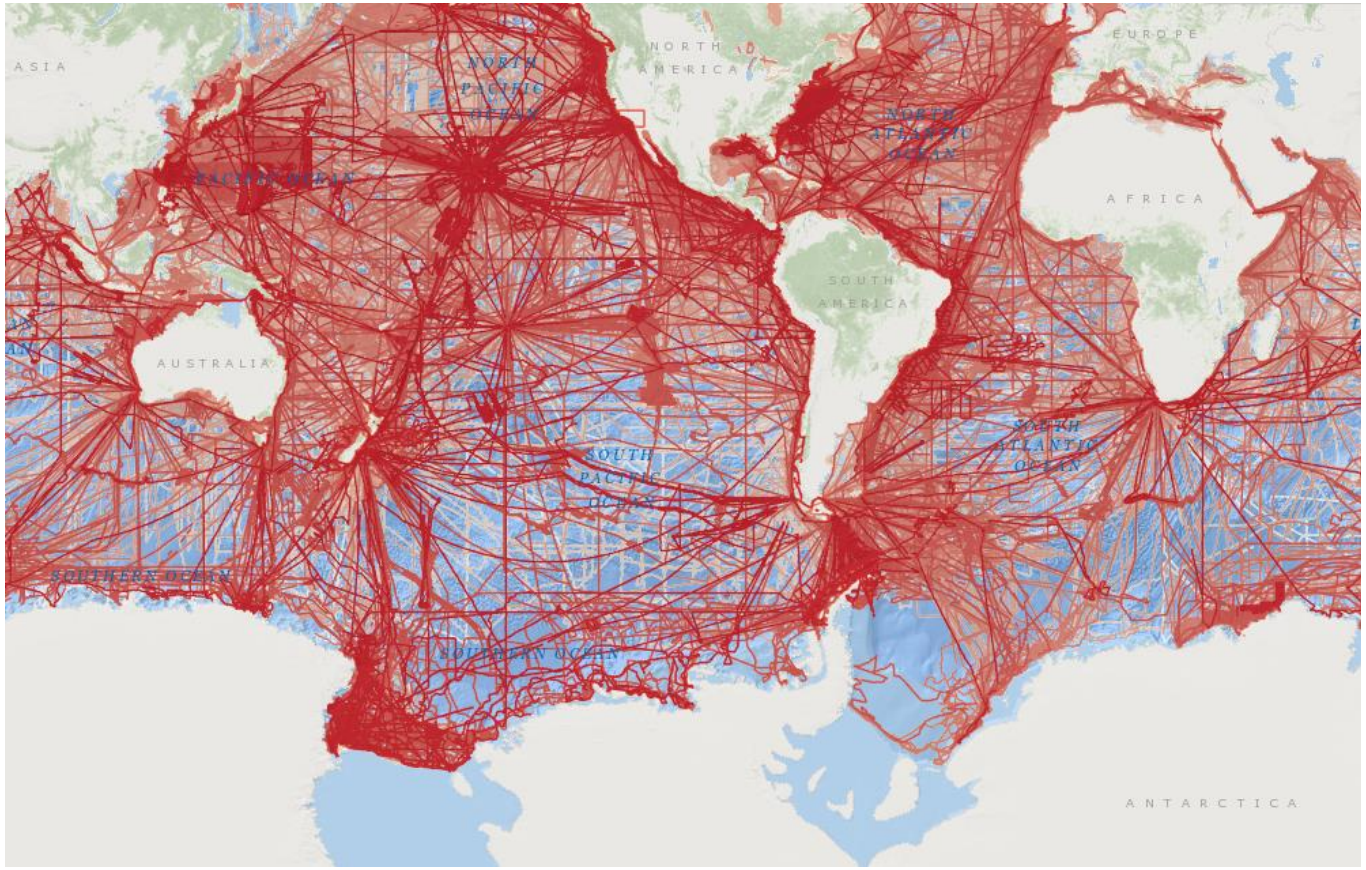
Daniel Woodworth and Kevin M. Gaastra
Rice University Department of Earth, Environmental, and Planetary Science



Trackline Data

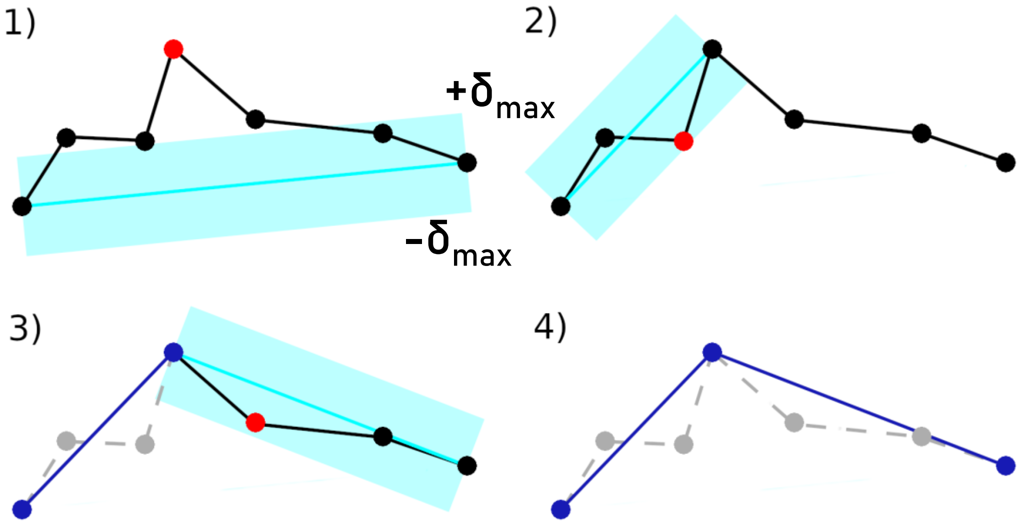
- Geophysical trackline data is widely available and used extensively
  - Skewness analysis of marine magnetic anomalies
  - Tectonic reconstructions
  - Crust and mantle structure

- Processing methods for trackline data are applicable across fields



Ramer-Douglas-Peucker Algorithm

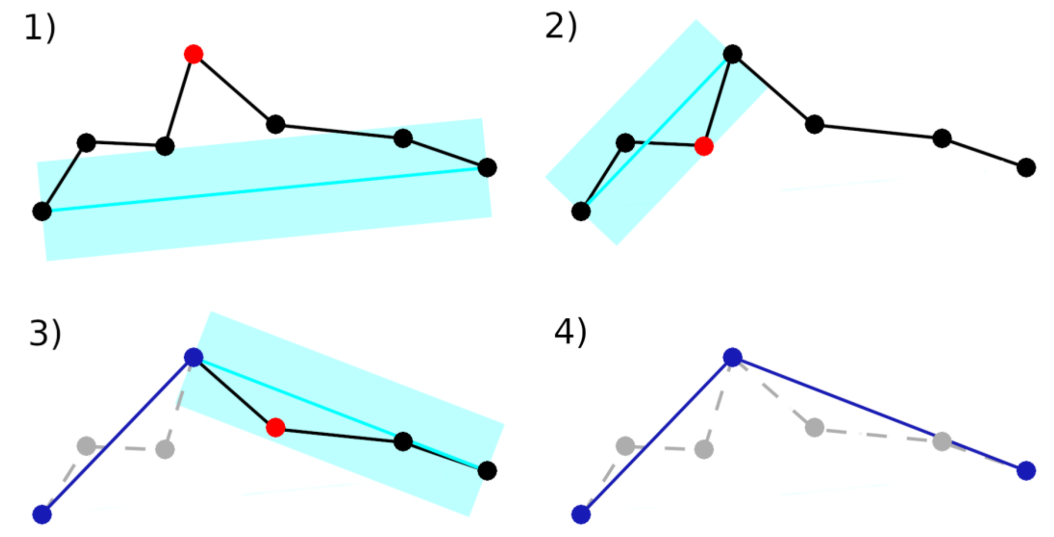
- Decimates curves to identify approximately straight segments.
- The furthest point beyond a distance threshold Δ_{max} from the chord connecting the first and last points of a segment defines a new segment endpoint.
- The same process is applied iteratively to all segments until now points lie beyond δ_{max} from the chord connecting the first and last points of any segment



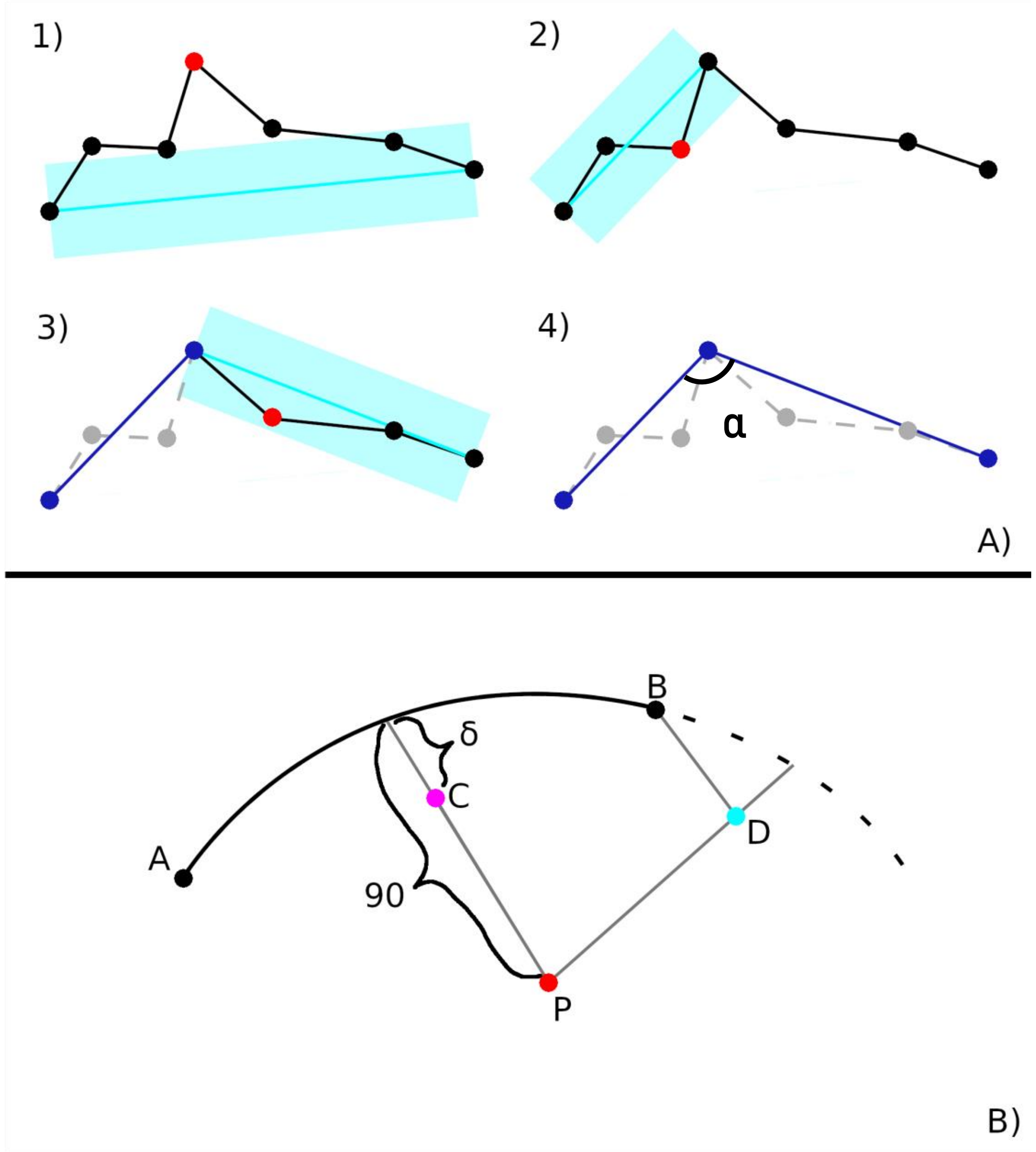
Ramer-Douglas-Peucker Algorithm

- ➢ Widely used in vector graphics and map generalization.

- ➢ Limitations for geophysical use:
  - Predominantly optimized for data compression.
  - Conventionally adapted to constant-bearing projections, without full spherical adaption.



RDP Spherical Adaptation



- Adapted for spherical coordinates and optimized for segmentation

- Cartesian distance is replaced by spherical distance
  $\delta = 90\text{-gc\_dis}(\lambda_C, \phi_C, \lambda_C, \phi_P)$

  - Where:
    λ_C is the latitude of the point in question,
    ϕ_C is the longitude of the point in question,
    λ_P is the latitude of the pole to the great circle connecting the endpoints,
    ϕ_P is the longitude of the pole to the great circle connecting the endpoints.

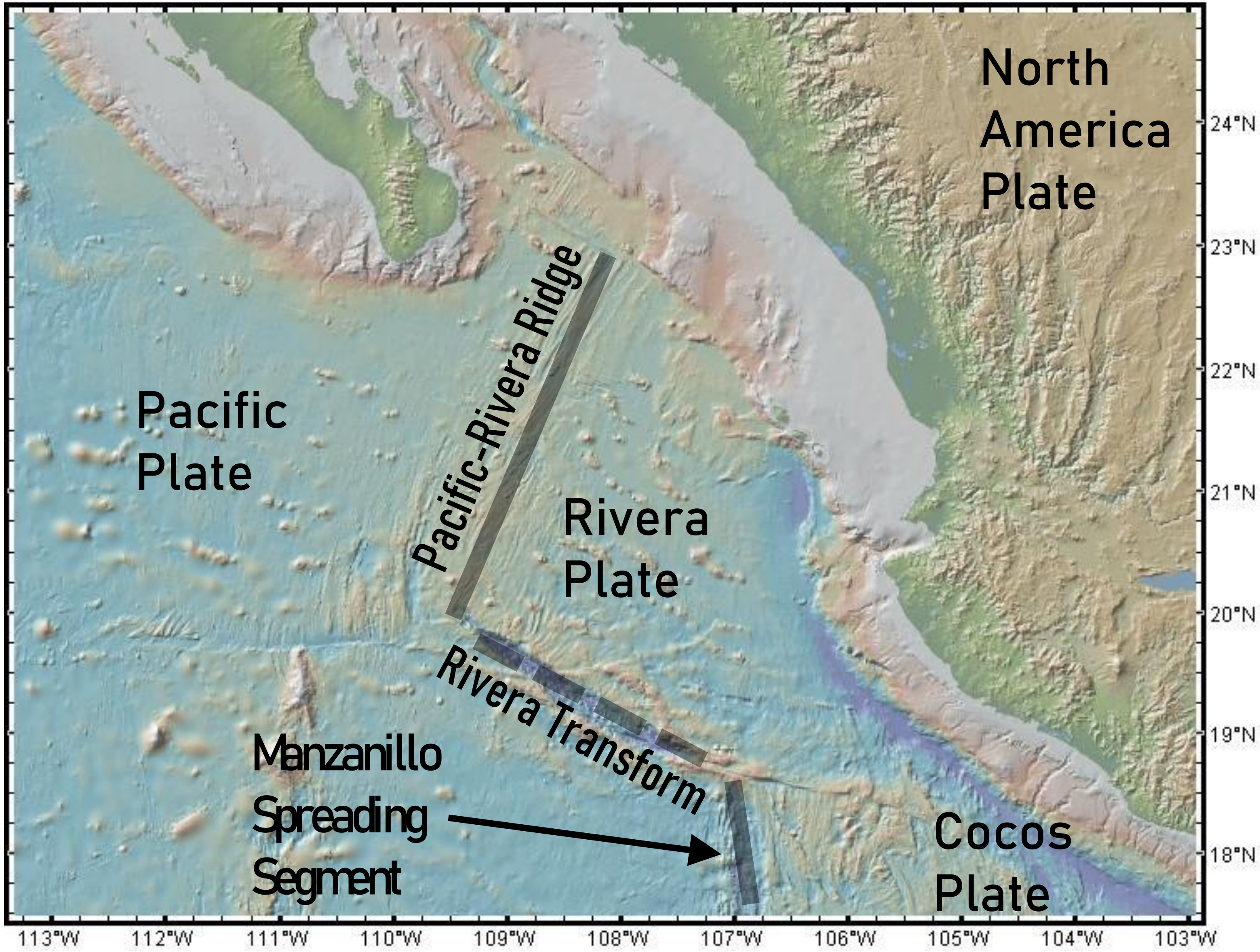
- Reduced track cut if segment heading differs by more than a threshold angle α_{min}

Application to Pacific-Rivera Spreading Rates

- Spreading rates along the Pacific-Rivera boundary make an ideal test case for the method

- Current Pacific-Rivera spreading rates have been estimated using by multiple studies (e.g. Lonsdale, 1995; DeMets & Wilson, 1997; DeMets et al. 2010)

- Magnetic tracklines are densely packed due to nearby ports



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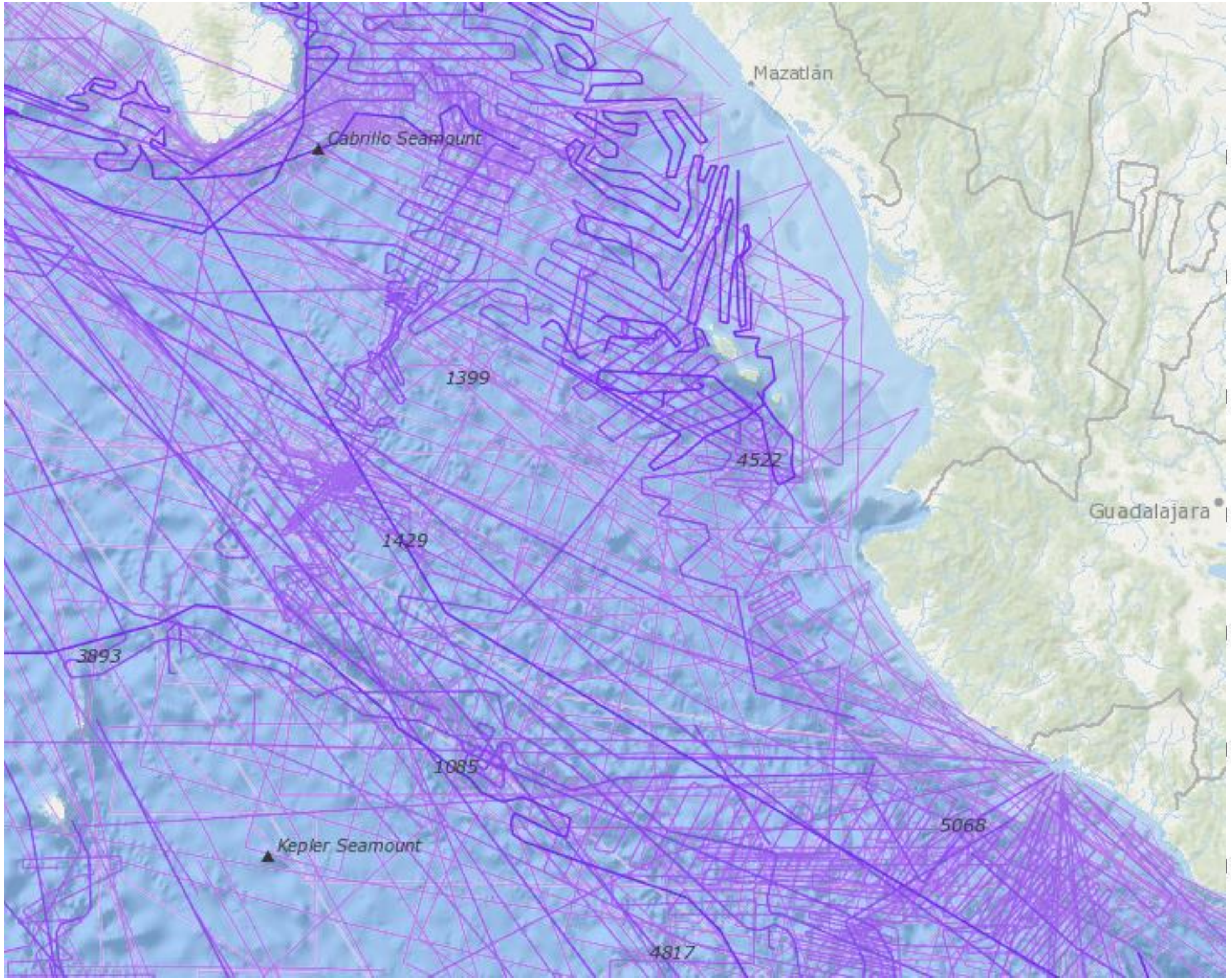
- Current Pacific-Rivera spreading rates have been estimated using by multiple studies (e.g. Lonsdale, 1995; DeMets & Wilson, 1997; DeMets et al. 2010)

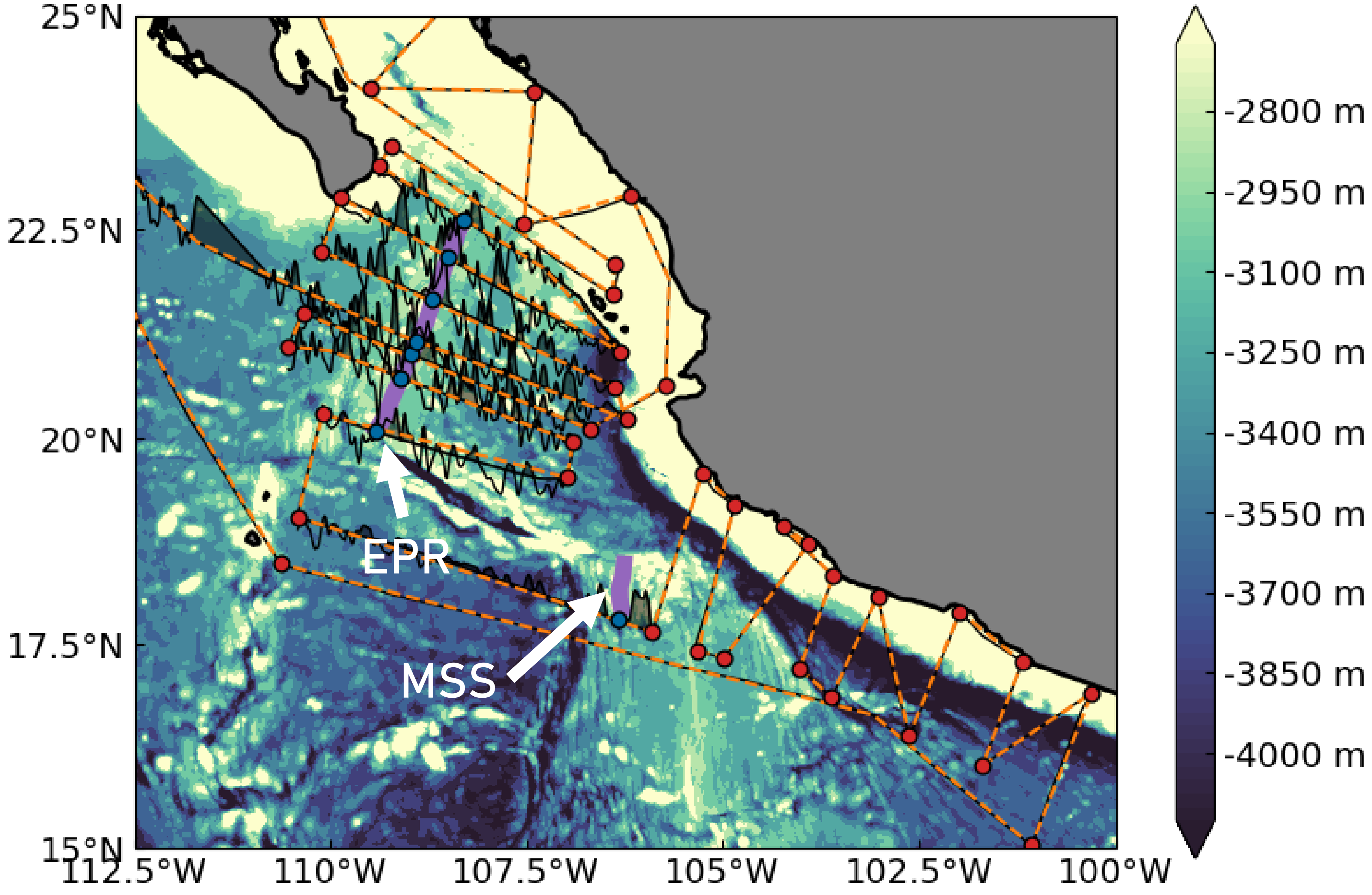
- Magnetic tracklines are densely packed due to ridge and nearby ports



Method

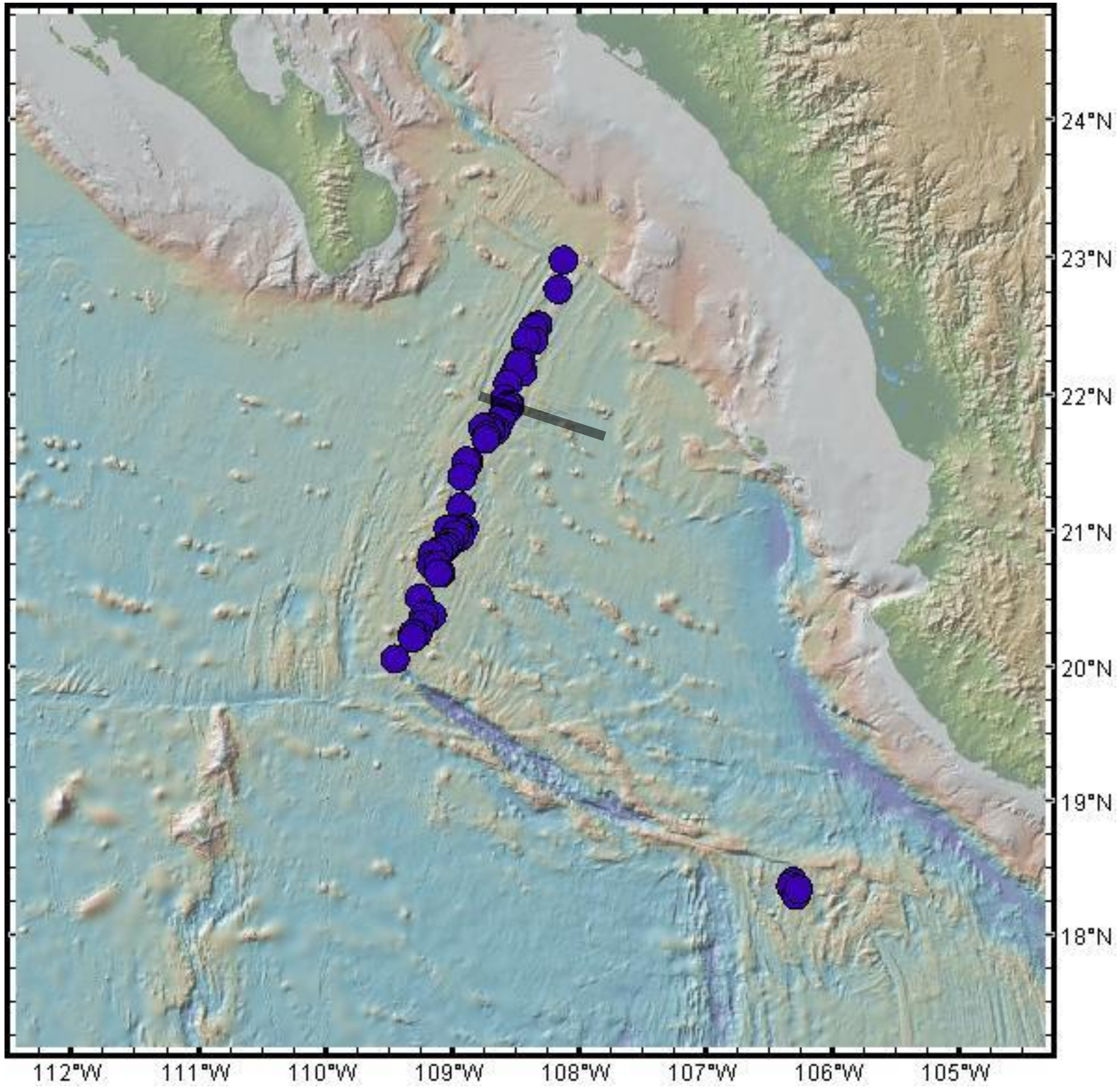
- Tracklines in the area of interest are selected from the NOAA NCEI geophysical trackline database.
- Tracklines are compared to digitized C1n isochron to check for crossings
- All tracklines with at least one crossing are processed using spherical RDP algorithm to identify ~straight segments.
- Each segment is checked for C1n crossings

Segmentation Example



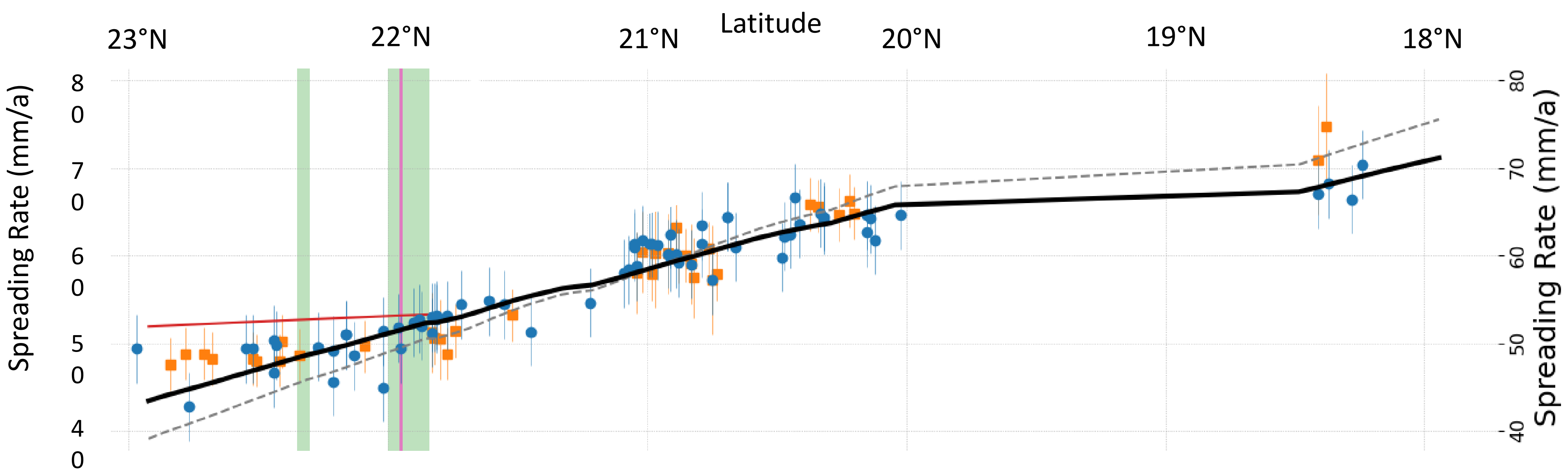
- MARSUR78
  δ_{max}=0.1°
  α_{min}=30°
- Algorithm identifies >30 segments in the area of interest
- Eight crossings identified in the region of interest
- Entire process complete in ~minutes

PA-RI Data



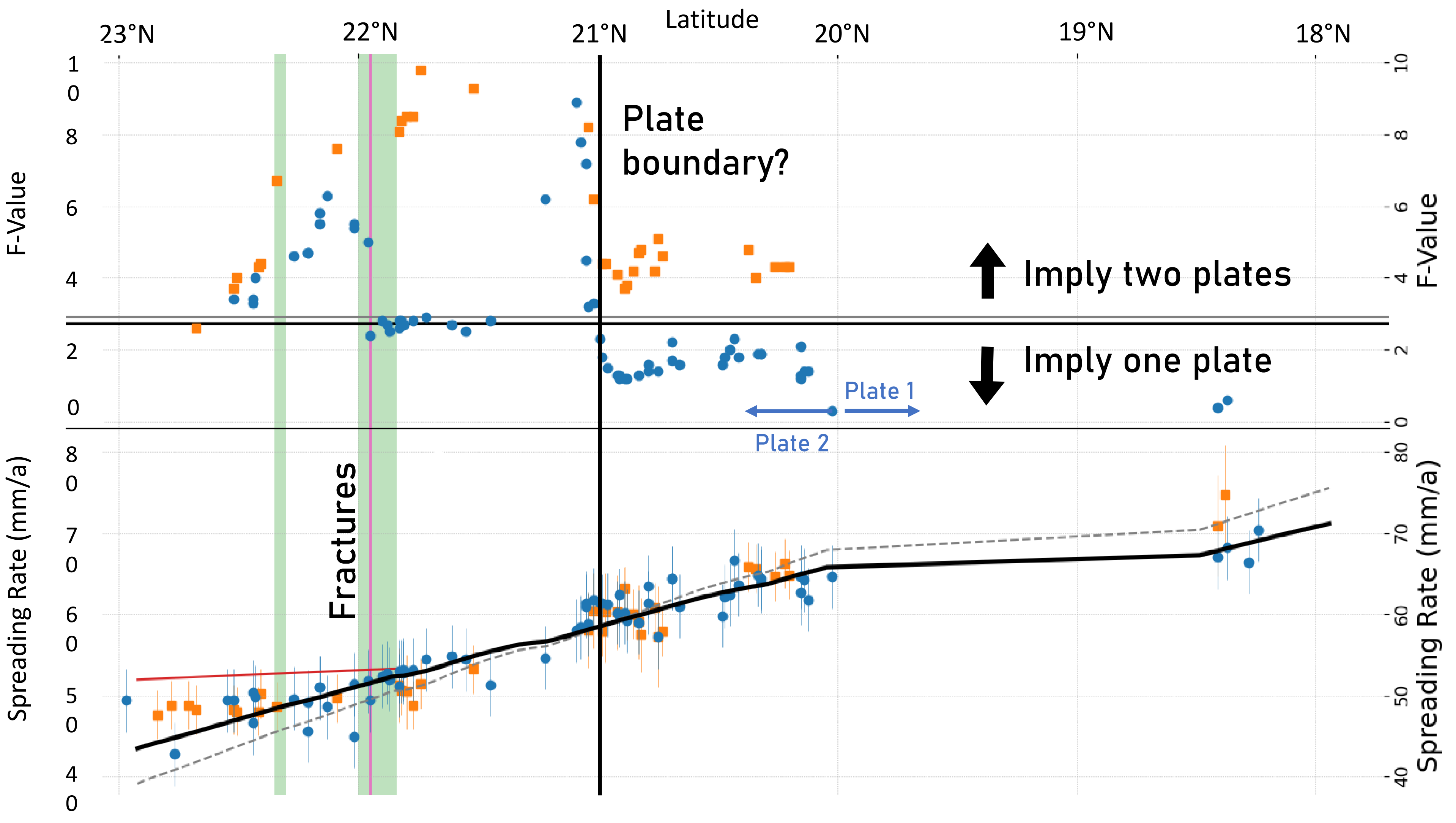
- We identify 465 interesting segments.
- After removing crossings potentially biased by topography, track characteristics, or incomplete data, we used 70 spreading rates in our analysis.
- This expands the MORVEL dataset by a factor of ~2, including in the geometrically important Manzanillo Spreading Segment.
- We invert these spreading rates together with MORVEL transform azimuths to find angular velocity.

Latitudinal Variation in Spreading Rate



- ➢ Our observed spreading rates (blue) are similar to MORVEL (orange)
- ➢ Our predicted rates from the angular velocity inverstion (black line) differ from MORVEL for the southern RI

Latitudinal Variation in Spreading Rate



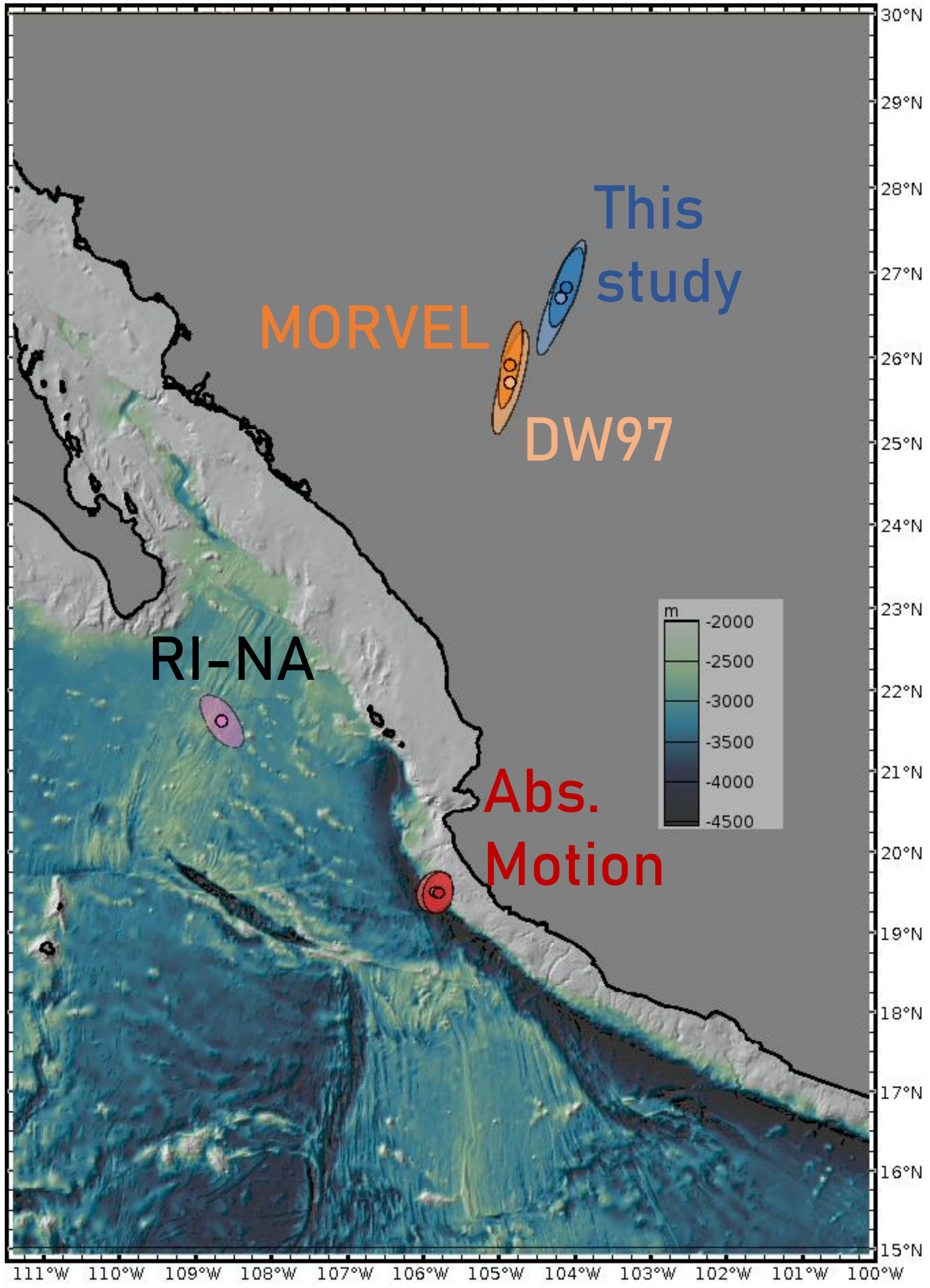
- At each crossing we use an F-test to determine whether the data are fit significantly better with a plate boundary at that latitude
- Critical F-values for our result (black) and MORVEL (gray)
- F-values rise near 21°N overlapping spreading,
- Consistent with northern boundary at 22°N fractures

Angular Velocity

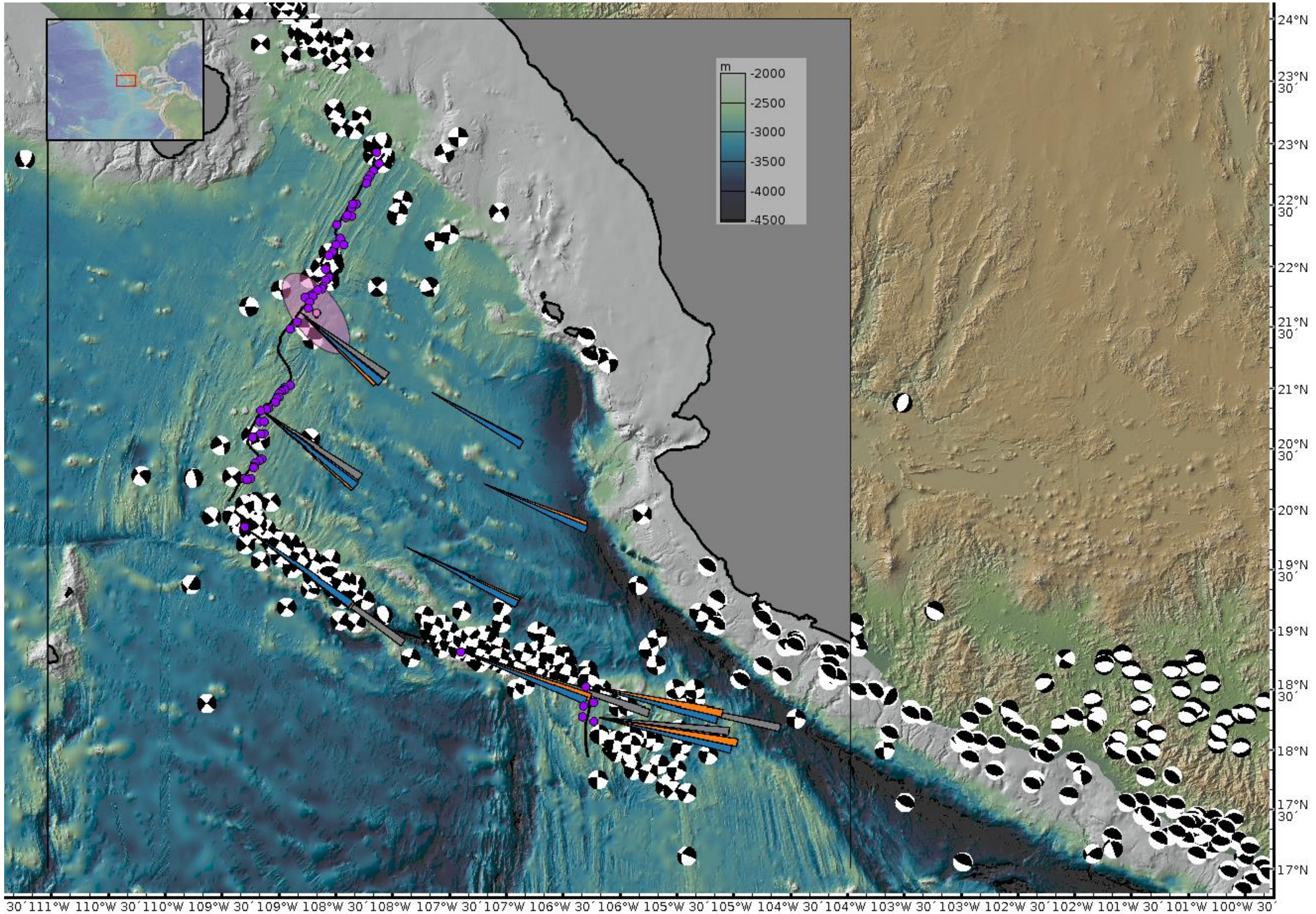
- Our preferred angular velocity (dark blue blue) is broadly similar to MORVEL (dark orange) and DeMets & Wilson (1997; light orange)

- However, our uncertainty ellipsoid is reduced by a factor of 0.5 compared to MORVEL due to our larger dataset and the use of both shipboard and aeromagnetic data.

- Our result differs significantly from previous results, largely due to newly identified crossings at the southern end of the Pacific-Rivera Ridge and in the MSS



Geological Interpretation



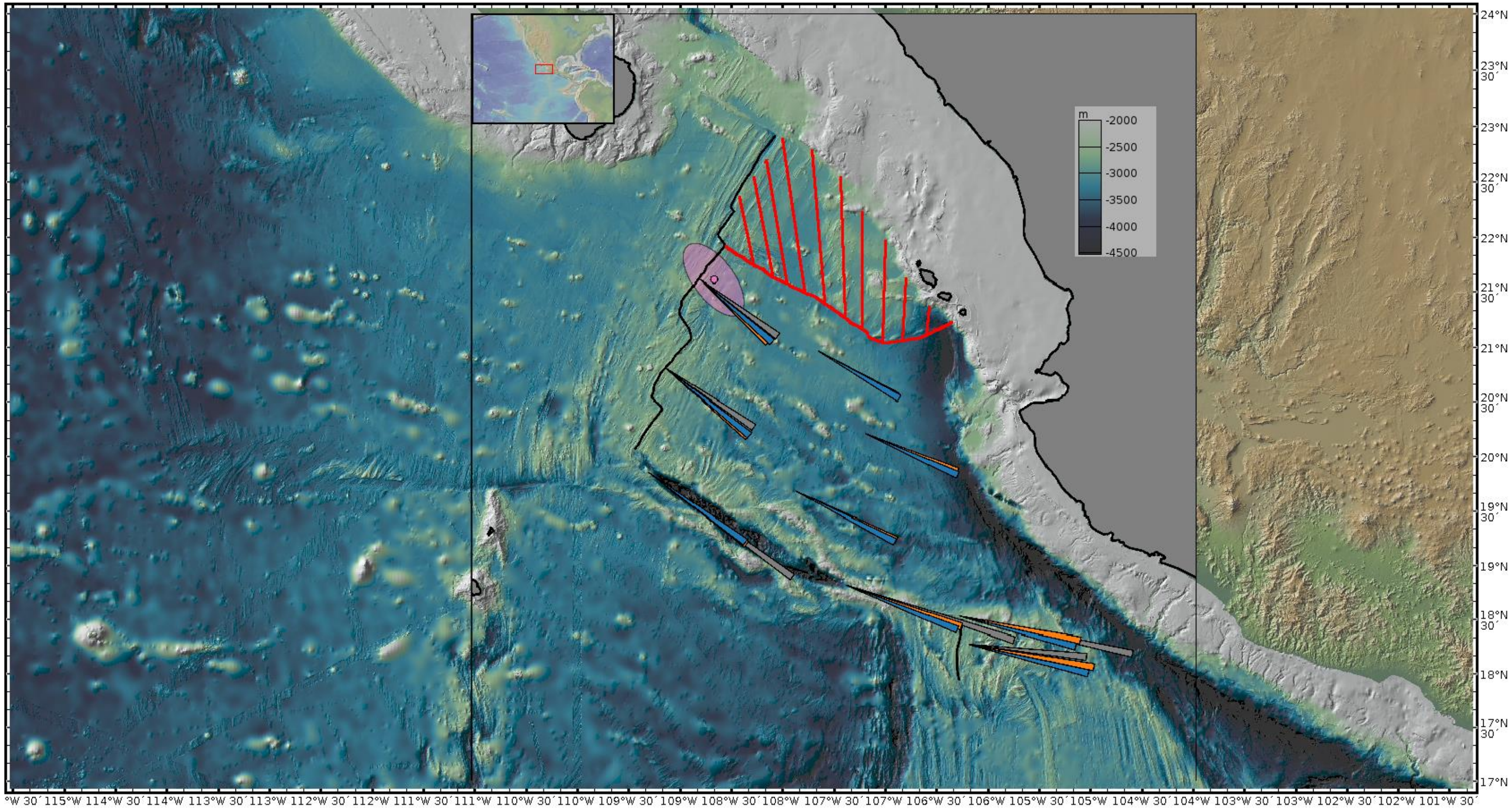
- Crossings plotted with earthquake focal mechanisms

- Cones indicate:
  1) Our predicted RI motion relative to the fixed Pacific (blue)
  2) MORVEL (orange)
  3) Observed (gray)

- Location of RI-NA pole between 21°N and 22°N suggests spreading rates should be consistent with RI-PA and NA-PA motion.

Geological Interpretation

- Our result confirms the presence of a northern RI fragment attached to NA.
- With additional data we provide additional support for placing this boundary along the ~22°N fractures.
- Our angular velocity better fits the PA-RI ridge and the MSS than MORVEL, but misfits the Rivera Transform more.



Summary and Future Applications

- We adapt the widely used RDP algorithm to be fully compatible with spherical geometry and optimized for segmenting geophysical trackline data.
- Applying this spherical RDP algorithm to crossings of the Pacific-Rivera Ridge, we identify 70 spreading rates, greatly expanding the available data with a minimum of effort.
- Our method allows a better constrained Pacific-Rivera relative motion angular velocity to be defined and a more detailed consideration of Rivera plate geometry.
- Future analysis of our Pacific-Rivera angular velocity may provide additional insight into plate geometry, particularly of the southern boundary of the Rivera plate.
- The spherical RDP algorithm we define will allow rapid segmentation of geophysical trackline data