Spatial Variation of slip behavior beneath the Alaska Peninsula along Alaska-Aleutian Subduction Zone

AGU Poster: G43B-0942

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December 10th, 2017

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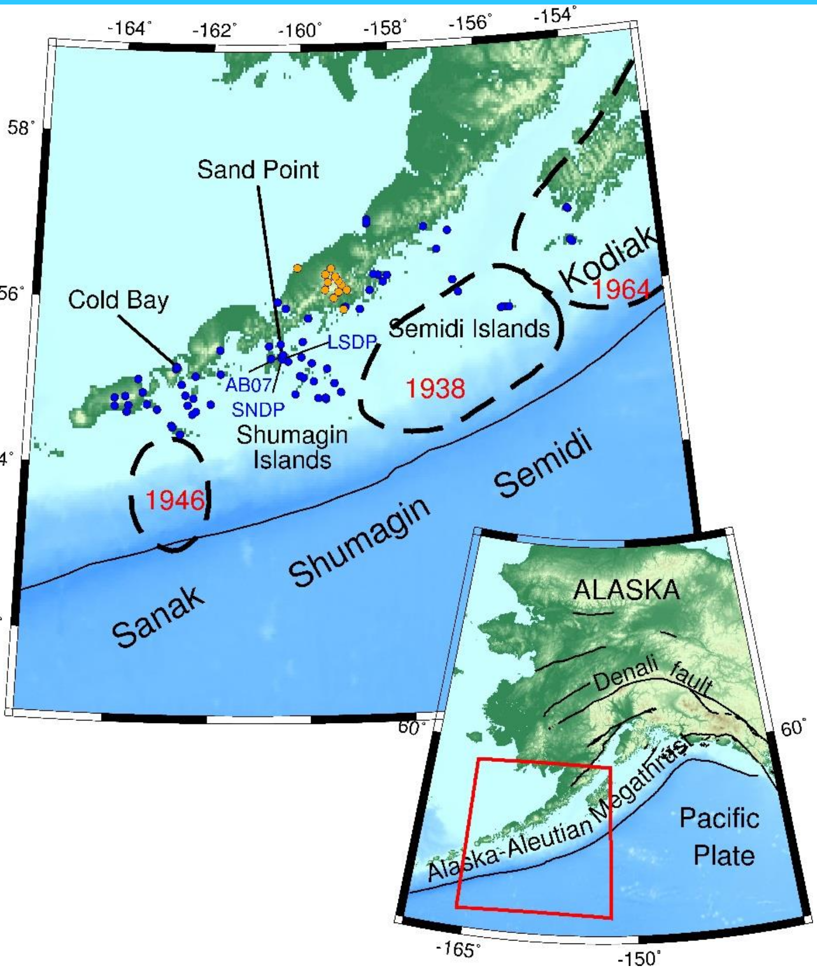
Notes: This work has been submitted to GRL.

Outline

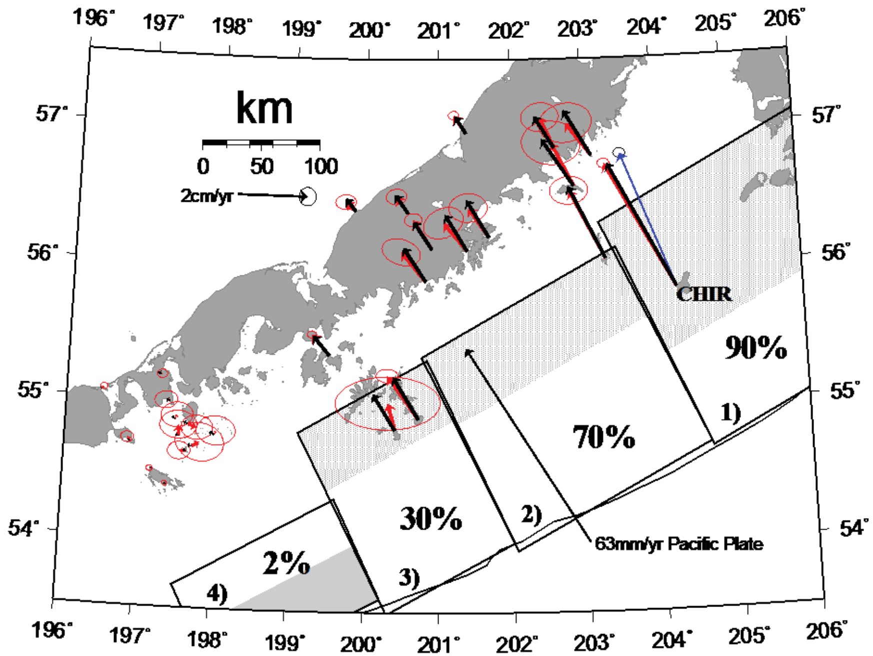
- Background and Motivation
- GPS Data
- Results
  - Inconsistency between the horizontal and vertical velocities
  - Three sharp boundaries that mark changes in fault locking
  - Correlation between the locking distribution and the plate fabric from magnetic anomaly, and subduction seismicity
- Conclusions
- Future Questions

Background and Motivation

Previous study of Along-strike Variation In Fault Coupling



Topographic map and tectonic setting of the study area on the Alaska Peninsula. **Blue dots** are GPS stations used in this study. **Orange dots** are GPS stations with significant volcano deformation.



Slip deficit model from Fournier and Freymueller (2007). Data (red) and model (black) velocity vectors are shown. All of the data have been corrected for arc translation (Cross and Freymueller, 2007)

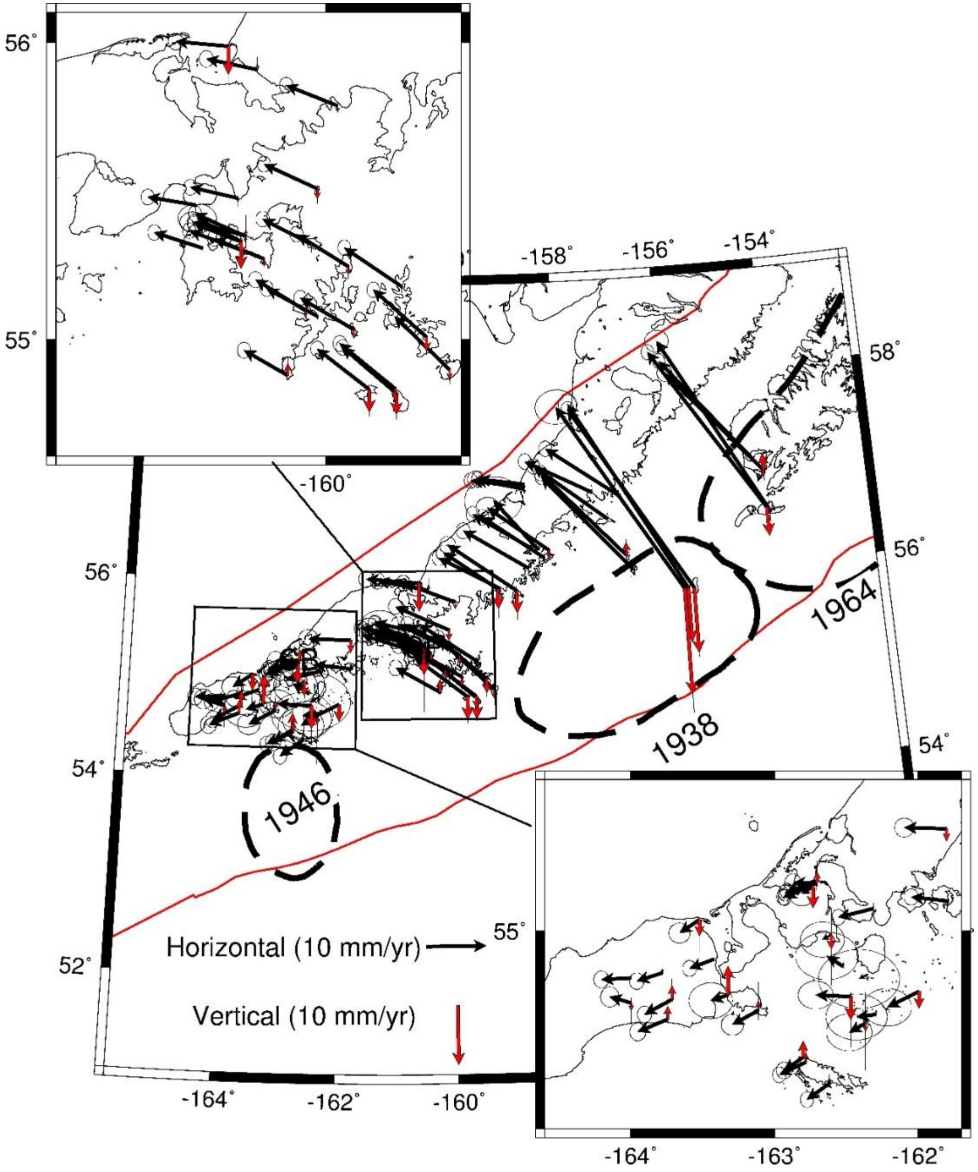
Research Motivation

1. Given a more dense GPS network, what is the along-strike variation in the locking distribution?

2. Does the estimated locking distribution correlate with features of the overriding or down-going plates from other observations?

GPS Data

New GPS Velocity Field



1. **Re-survey pre-existing campaign GPS sites** (35 sites) within Shumagins and the 1938 rupture zone to the northeast in May – June 2016;

2. Current GPS site network has much **lower uncertainties** than the previous one;

3. **Site velocity constant in time** except one SSE (eg. Station AB07).

Example of GPS Time Series

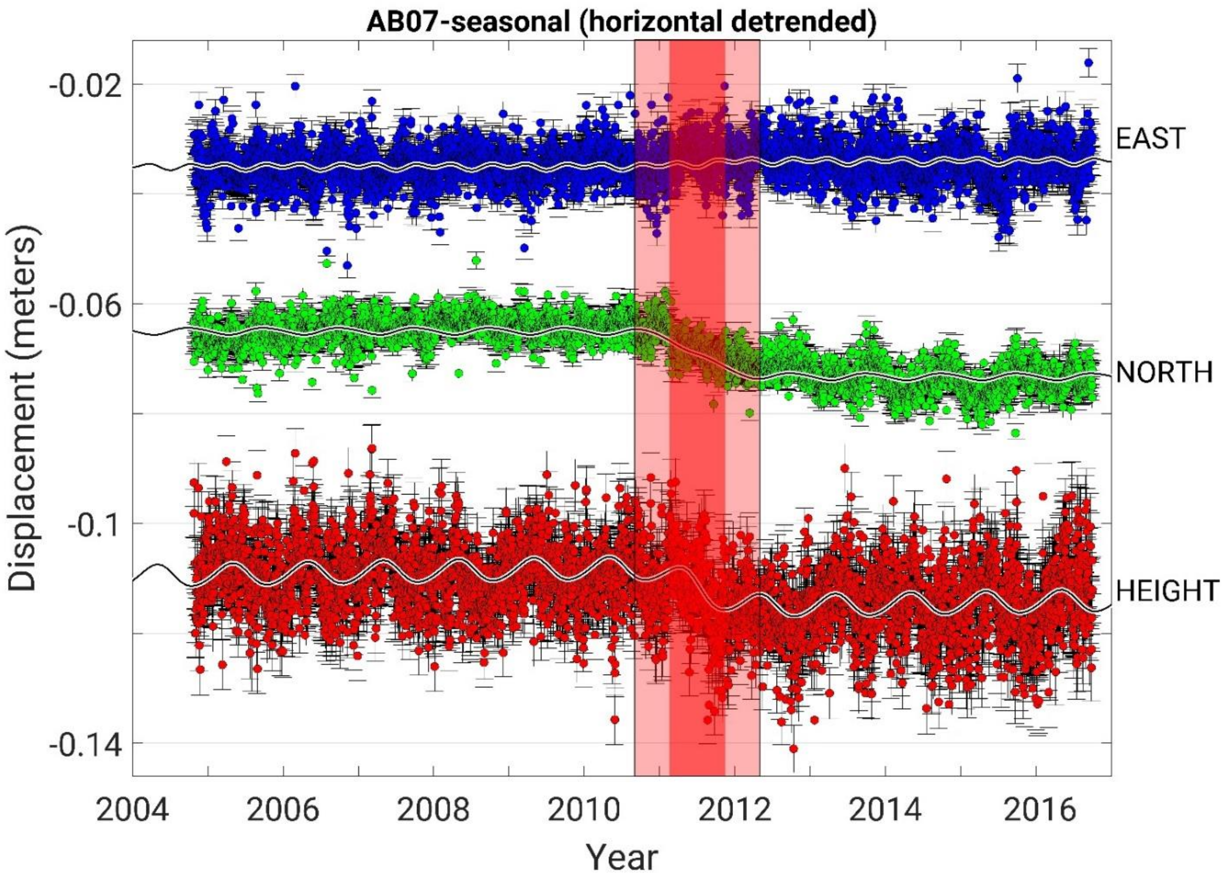


Figure 5. Time Series of GPS station AB07, detrended based on pre-SSE velocity (GRACE-derived seasonal variation removed and residual seasonal terms are estimated and shown). The strongly shaded area contains 68% SSE deformation (2011.5 ± 0.37). The weakly shaded area contains 95% SSE deformation (2011.5 ± 0.83). The counterpoint of the event at 2011.5.

Results

Results

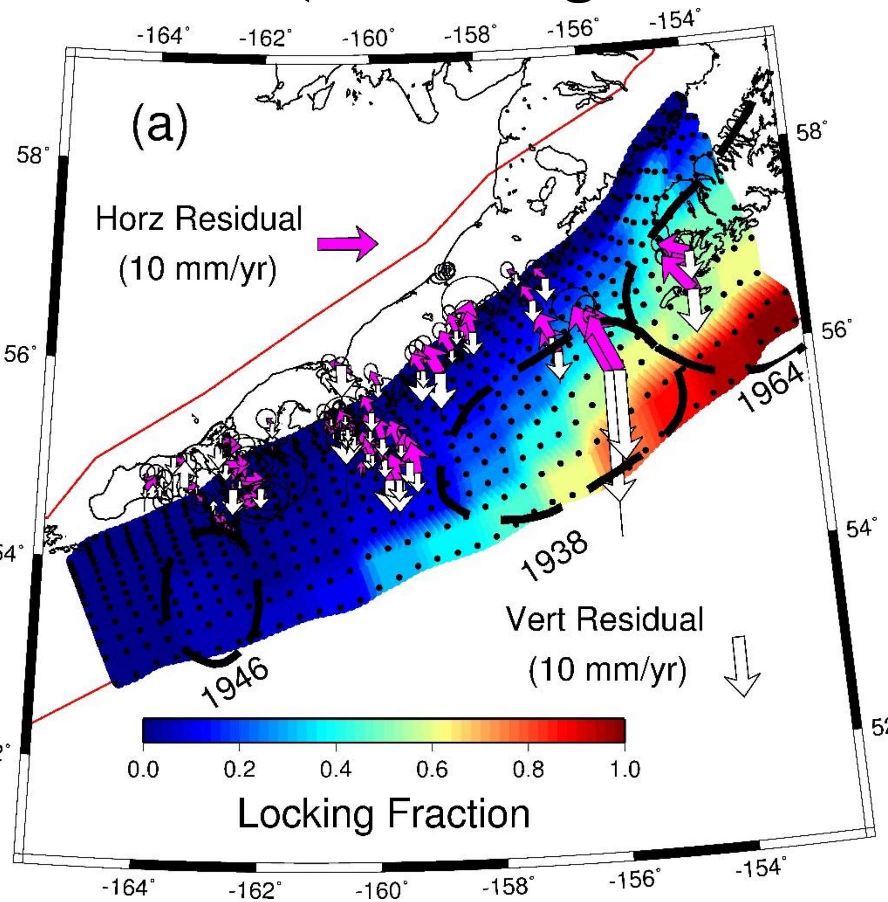
- **Inconsistency between the horizontal and vertical velocities**

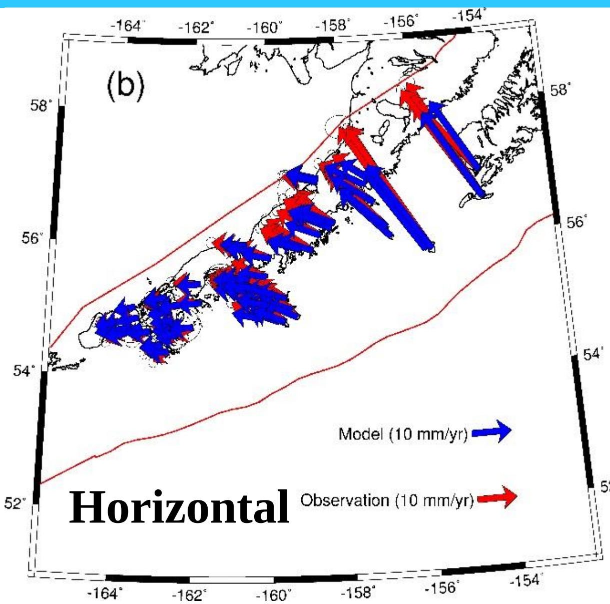
- Three sharp boundaries that mark changes in fault locking

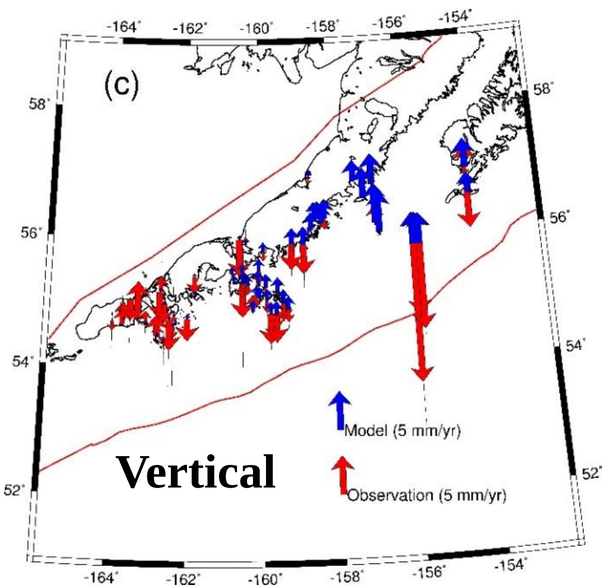
- Correlation between the locking distribution and the plate fabric from magnetic anomaly, and subduction seismicity

Inconsistency between horizontal and vertical velocities

Best fit model for inverted locking distribution by using horizontal and vertical velocities both **<u>(smoothing factor = 4e8)</u>**







Inconsistency between horizontal and vertical velocities

Possible factors explaining the inconsistency:

- Differences in the published geometry of the plate interface
  ---- Do not explain the inconsistency
- Glacial Isostatic Adjustment
  --- Existing models do not explain it
- Reference frame errors
  --- Do not explain it

For the following models, we only use horizontal component of GPS velocities.

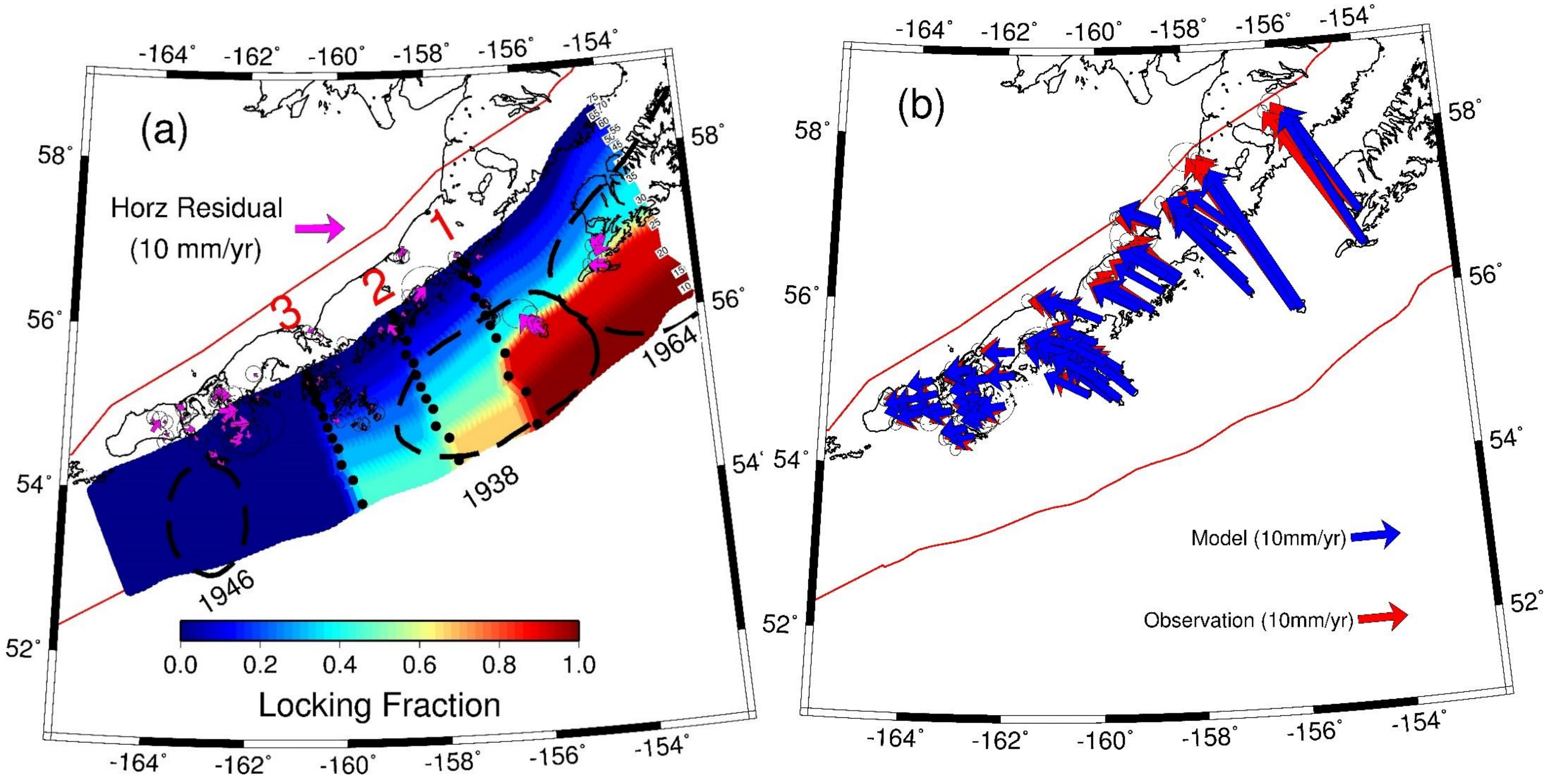
Results

- ❑ Inconsistency between the horizontal and vertical velocities

- ❑ **Three sharp boundaries that mark changes in fault locking**

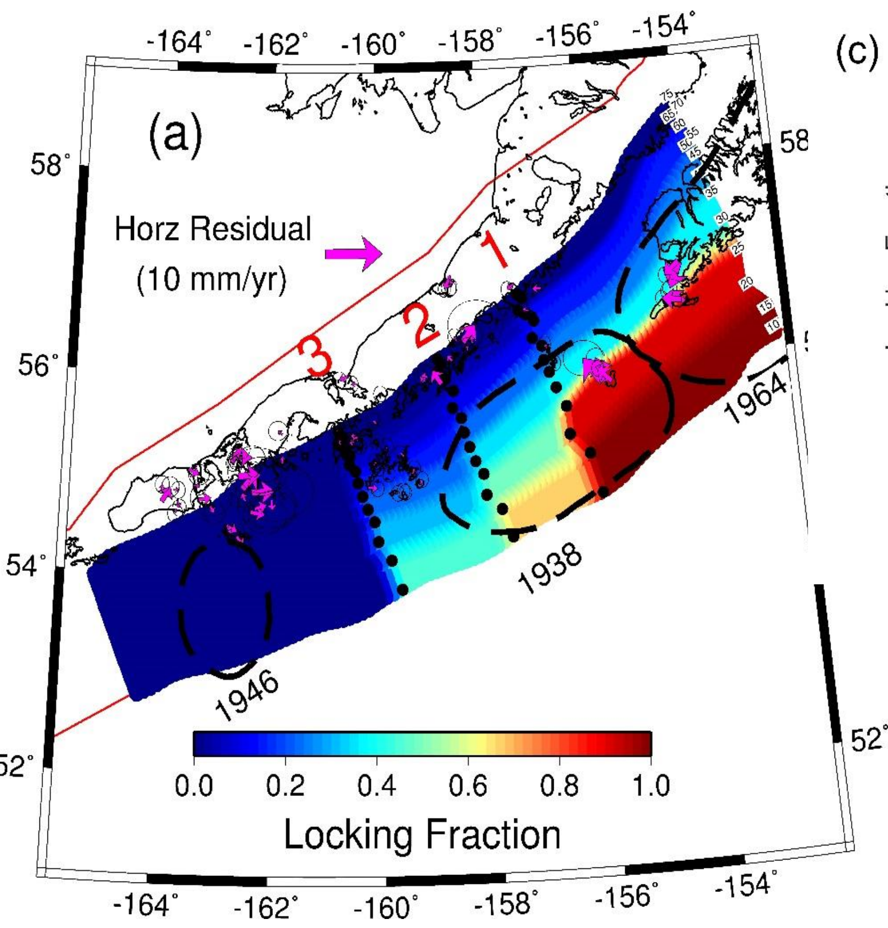
- ❑ Correlation between the locking distribution and the plate fabric from magnetic anomaly, and subduction seismicity

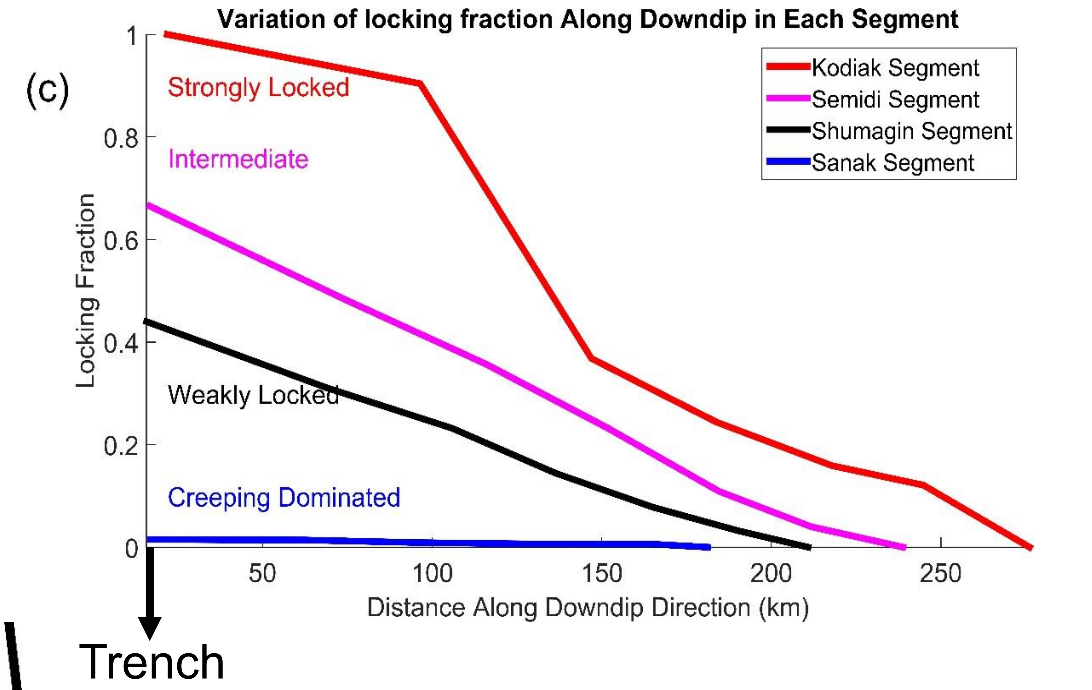
Three Sharp Boundaries that Mark changes in Fault Locking



Optimal Model

Three Sharp Boundaries that Mark changes in Fault Locking



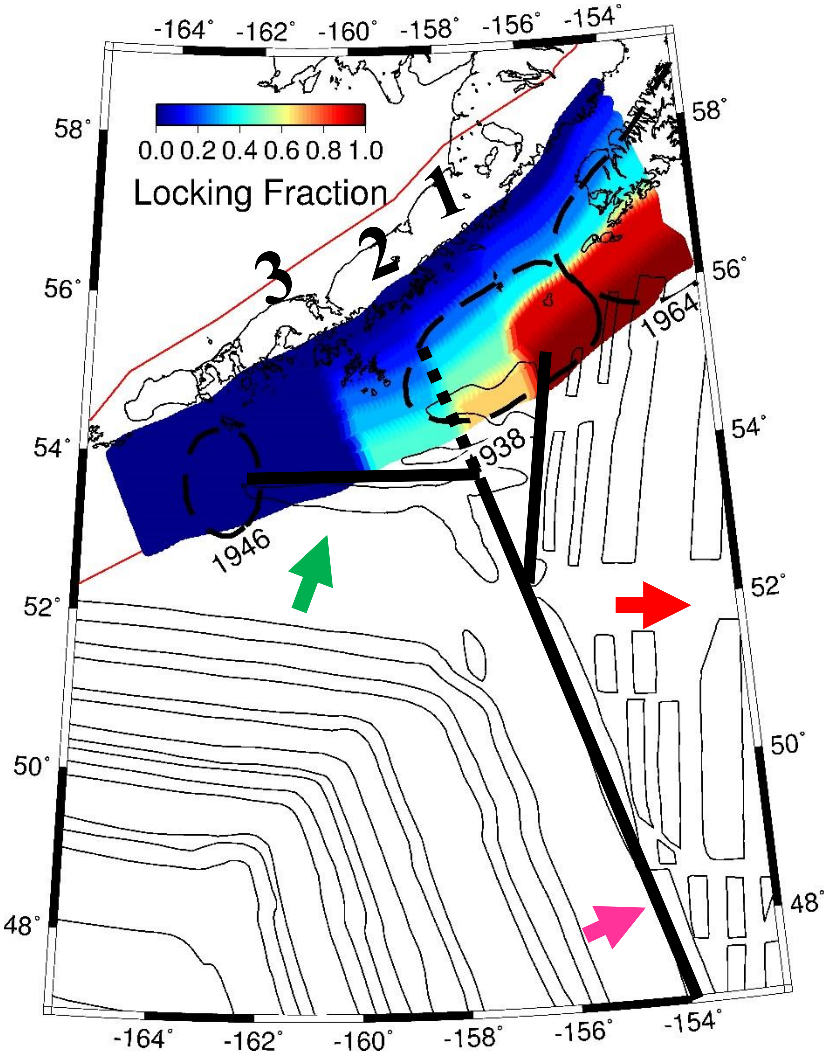


1. Obvious step-wise decreases in the width of the locked region from the NE to SW along-strike;
2. A sharp decrease from strongly locked to weakly locked within a short distance from trench towards downdip in the Kodiak segment

Results

- ❑ Inconsistency between the horizontal and vertical velocities
- ❑ Three sharp boundaries that mark changes in fault locking
- ❑ **Correlation between the locking distribution and the plate fabric from magnetic anomaly, and subduction seismicity**

Locking Distribution vs. Pre-existing Fabric



Digital Magnetic Anomaly polygons provided by Peter Haeussler and Keith Labay
[Origin: Atwater 1989; Atwater and Severinghaus, 1989]

- Kula-Pacific spreading center
- **Average rate ~60 mm/yr**
- **Spreading age: 80 to 56 Ma (44?)**

- Farallon-Pacific spreading center
- **Half rate ~40 mm/yr**
- **Spreading age: 100 to 55 Ma**

- Vancouver-Pacific spreading center
- **Similar rate as Farallon-Pacific**
- **Spreading age: 53 to 30 Ma**

Boundary 1:

the **cessation of the Kula-Pacific spreading** (intermediate locked) and **beginning of the Vancouver-Pacific spreading** (strong locked).

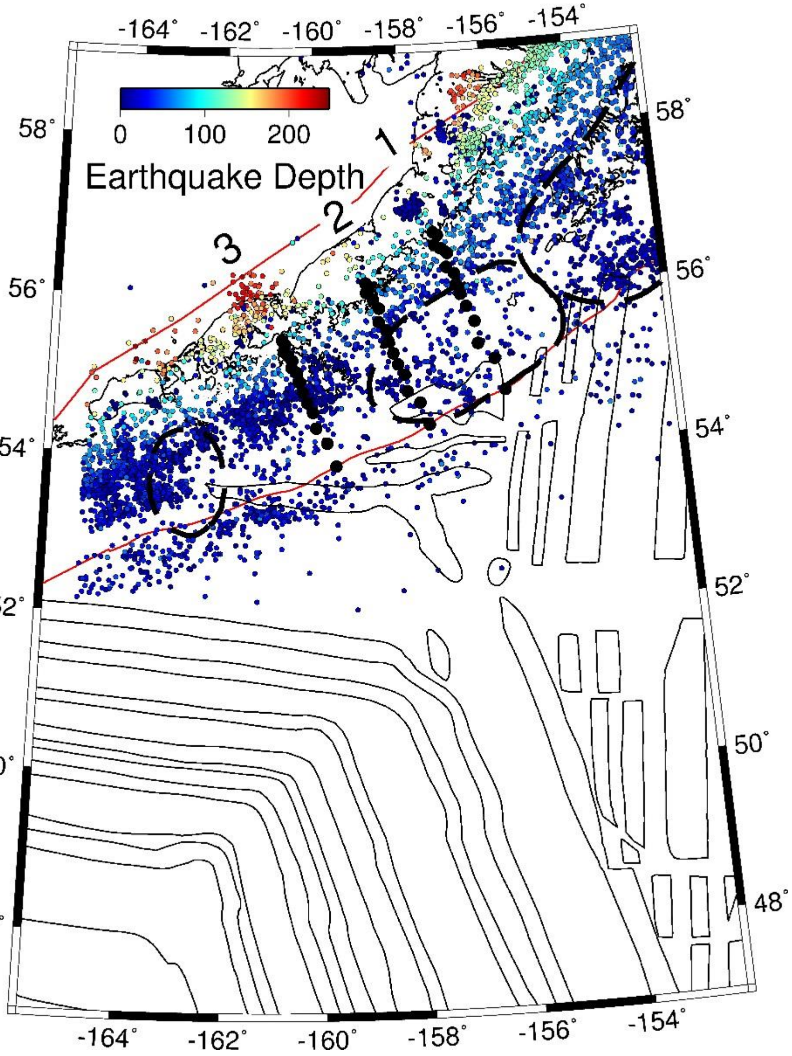
Boundary 2:

the **northern portion of the Farallon plate broke off** and became the Vancouver plate.

Boundary 3:

a major orientation change in two younger sections of pre-existing fabric near the trench (A triple junction or the attachment of Kula-Pacific spreading?).

Locking Distribution vs. Subduction Seismicity



Seismicity (Magnitude > 3.0) from the Alaska Earthquake Center from 1990 to present

Shallow earthquakes:

- More common in the creeping-dominated area and near trench in the strongly locked area, less common in between.

Outer-rise earthquakes:

- More abundant in the creeping-dominated area

Intermediate-depth earthquakes:

- More in the creeping-dominated area and in the strongly locked area, then less in between.

Conclusion

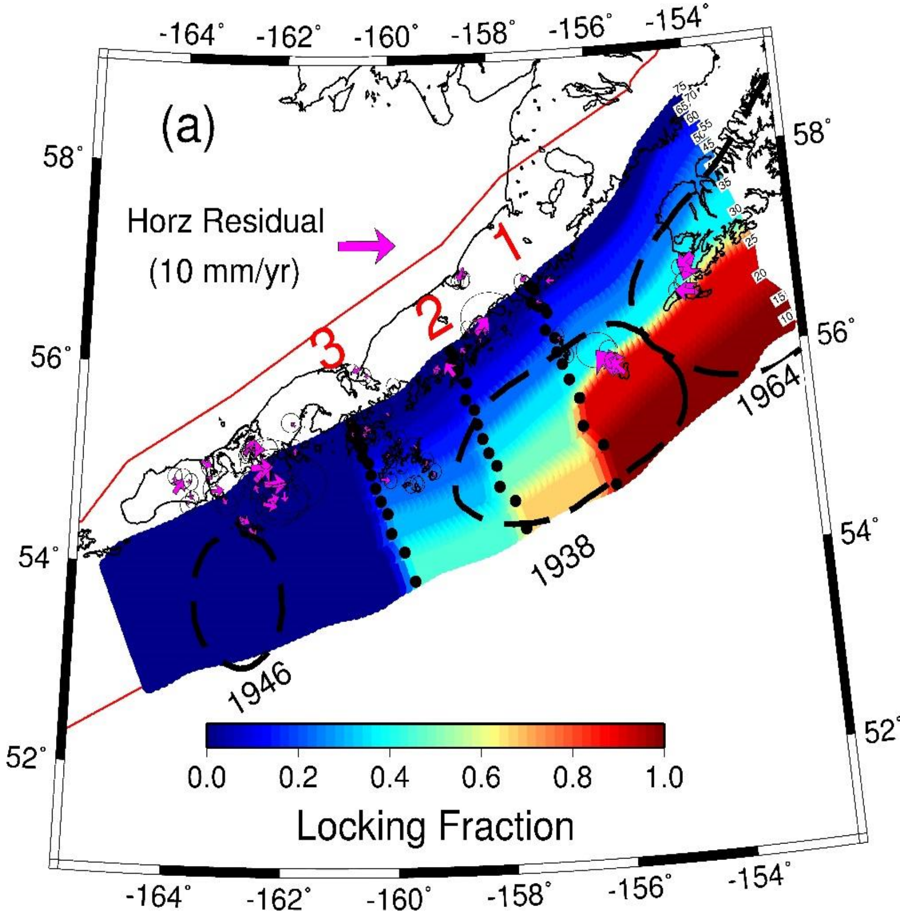
1. There is an inconsistency between the horizontal and vertical velocities, and long-wavelength systematic misfits in the vertical velocities still remain unsolved.
2. The width of the locked region decreases step-wise from NE to SW along strike.
3. There are three sharp boundaries separating segments with different fault locking.
4. The changes in pre-existing seafloor fabric orientation contributes significantly to the change in fault locking and subduction seismicity.

Future Questions

Future Questions

Question 1:

Given the **three sharp boundaries** that we found in the estimated locking distribution, are there other properties (eg. evidence of potential active faults, sediment structure, etc) that correlate with these boundaries with **new seismic observations** (eg. P-wave velocity, seismic reflection, earthquake mechanism, etc.)?

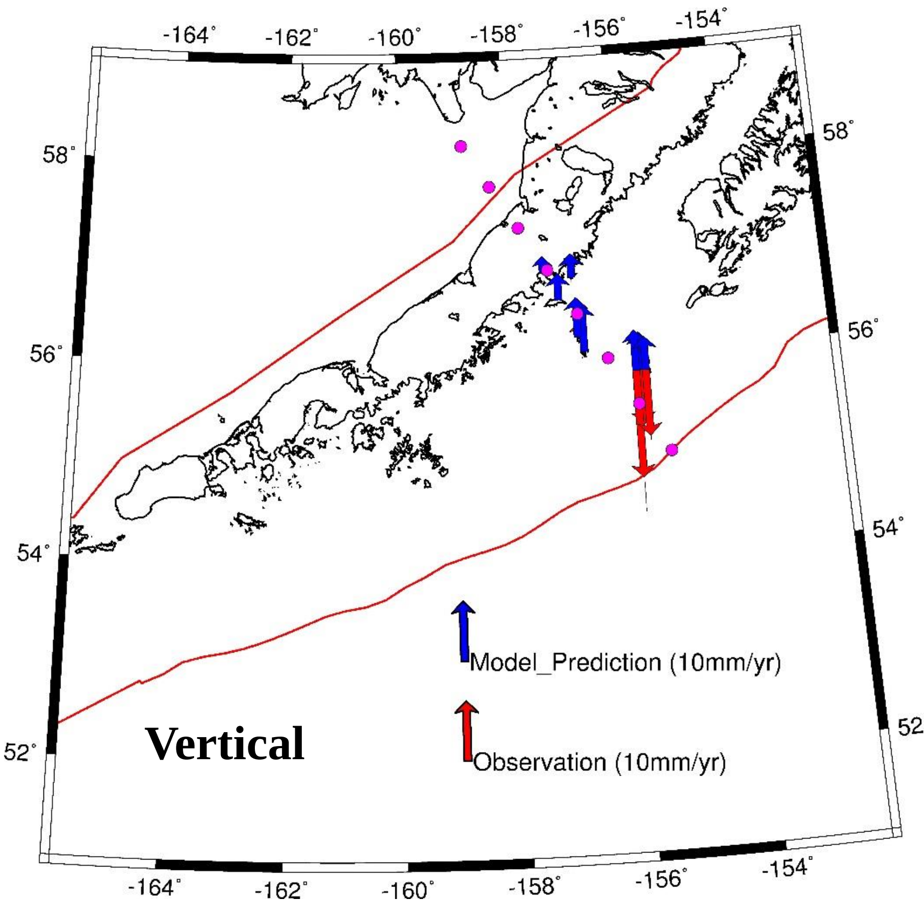


Future Questions

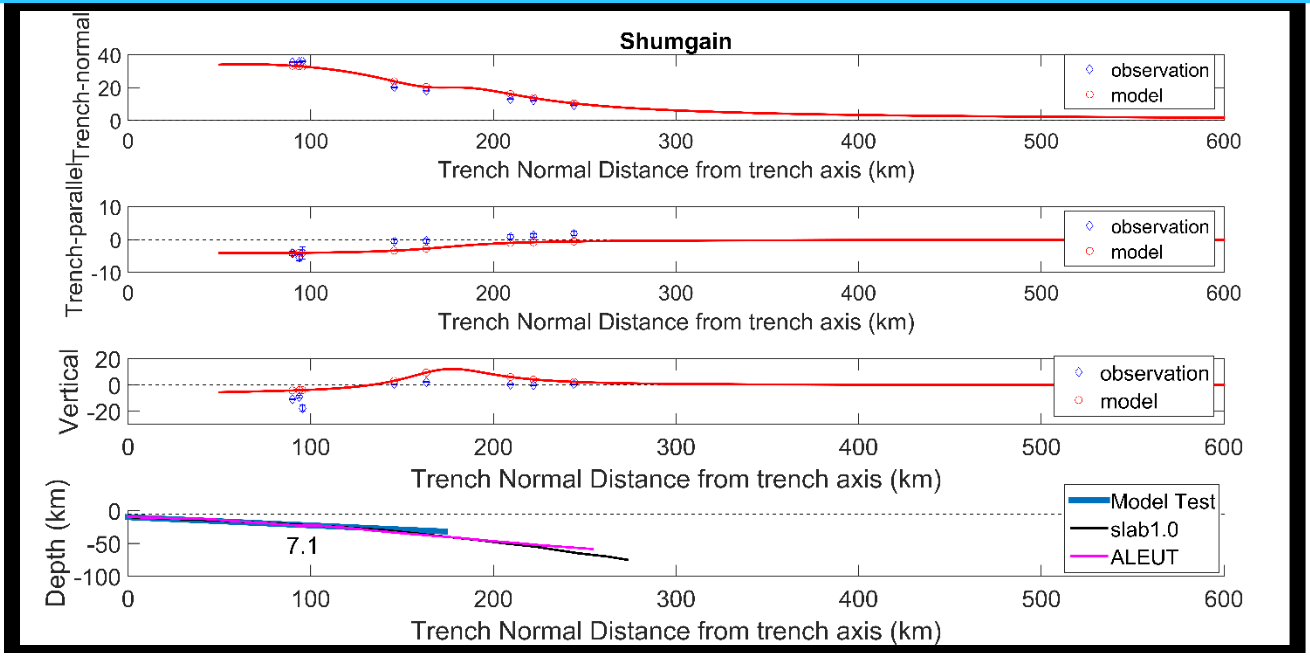
Question 2:

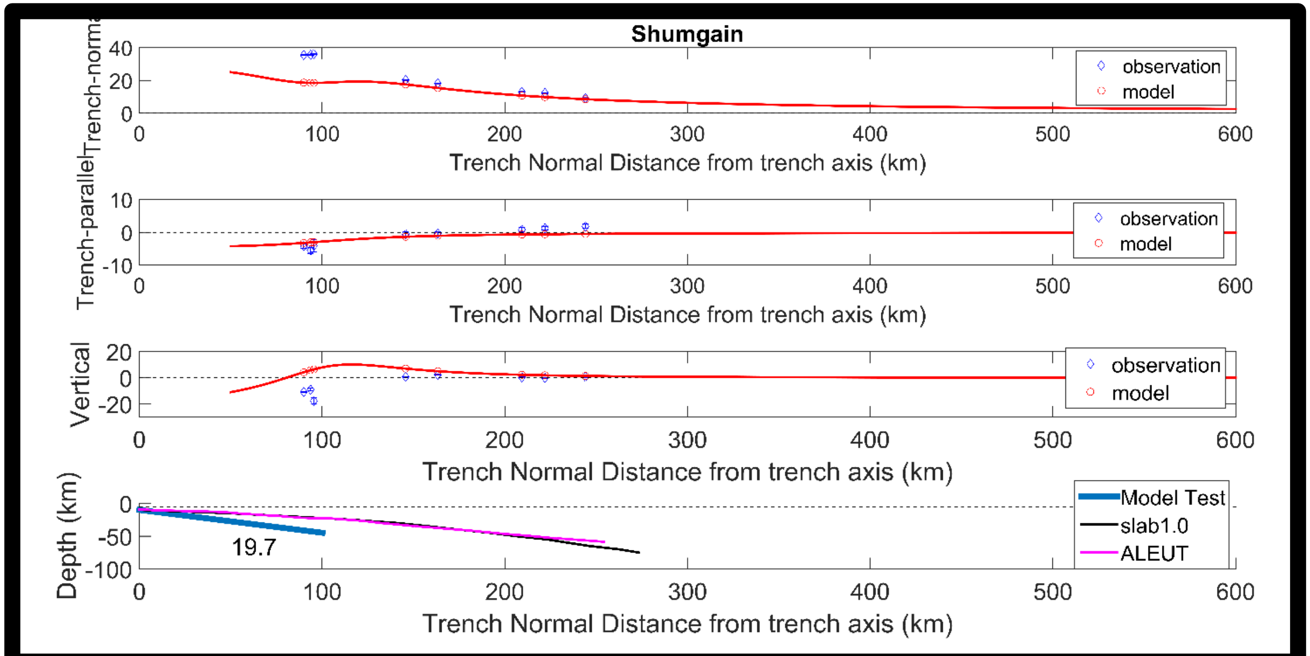
Can a different plate interface model, especially in the shallow region, fit the geodetic data better?

- Is all slip on the plate interface? Or is there a combination of slip on the plate interface and an active fault near the trench? An active fault in the forearc might better predict deformation on Chirikof Island.
- What exactly is the geometry of the slip interface located?



Future Questions



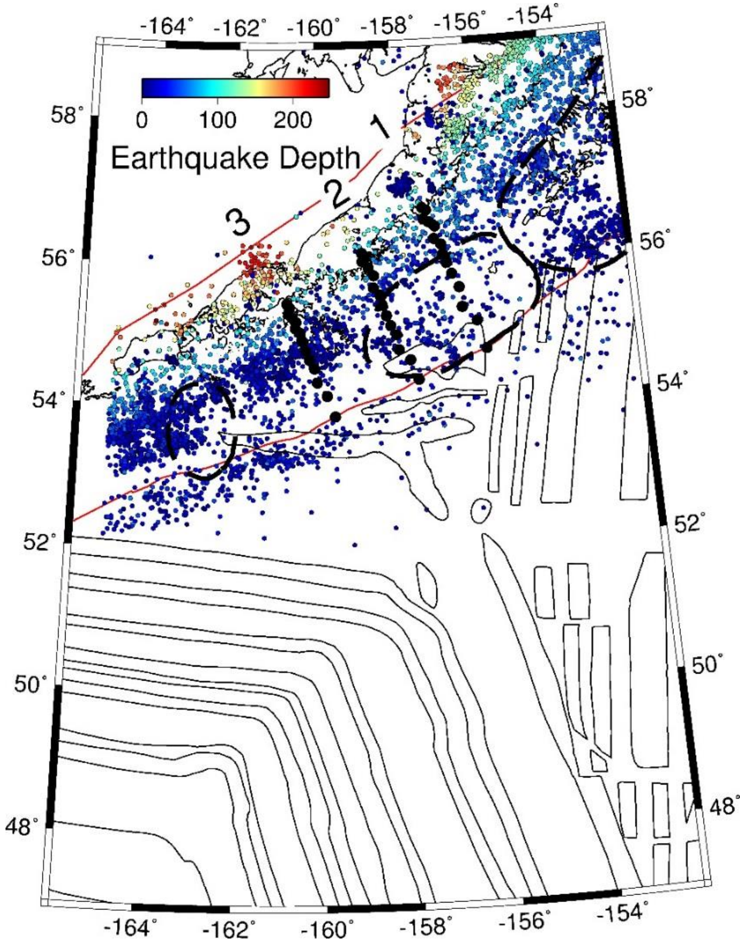


Future Questions

Question 3:

Can improved seismic observations help explain **the short wavelength variation in shallow earthquakes and intermediate-depth earthquakes**?

- At what depth do those shallow earthquakes occur? Are they plate interface events or in the upper plate? What possible mechanisms might explain their correlation with locking of the interface?
- What is a possible mechanism for abundant intermediate-depth earthquakes in strongly locked area?



Thank you !

Spatial Variation of Slip Behavior beneath the Alaska Peninsula along Alaska-Aleutian Subduction Zone

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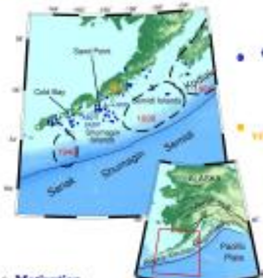
Poster: G43B-0942

Geodynamic Processes at Rifting and Subducting Margins — GeoPRISMS

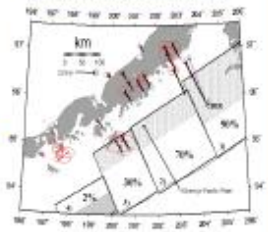
UAF College of Natural Science & Mathematics, University of Alaska Fairbanks

1. Introduction and Background

a. Study Area (Figure 1)



b. Previous Study (Figure 2) (Fournier and Freymueller 2007)



c. Motivation

1. Given a more dense GPS network, what is the Along-strike variation in the locking distribution?

2. Does the estimated locking distribution correlate with features of the downgoing plates from other observations?

2. GPS Data and Block Model

a. Previous vs Current GPS Site Network in the Alaska Peninsula

1. Re-survey pre-existing campaign GPS sites (35 sites) in May – June 2016;

2. Current GPS site network has much lower uncertainties than the previous one;

3. Site velocity constant in time except one SSE (eg. Station AB07).

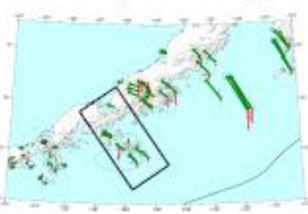


Figure 3. GPS Data in Previous Study

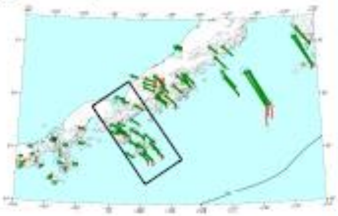


Figure 4. GPS Data in Current Study

b. Example of GPS Time Series for Station AB07

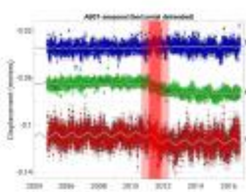


Figure 5. Time Series of GPS station AB07, detrended based on pre-SSE velocity. The strongly shaded area is 68% SSE deformation. The weakly shaded area is 95% SSE deformation. The SSE has a center-point of the event at 2011.50.

c. Block Model

The estimated angular velocity of the PENN block in Li et al. (2016) used data from Cook Inlet and Alaska Peninsula, which appears to be moving slightly faster (~1 mm/yr) than the Alaska Peninsula and the eastern Aleutians, leading to systematic trench-parallel residual in the GPS velocities here.

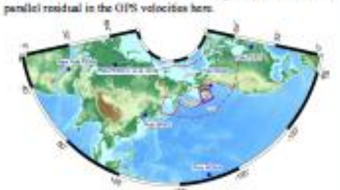
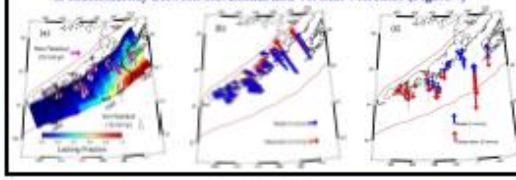


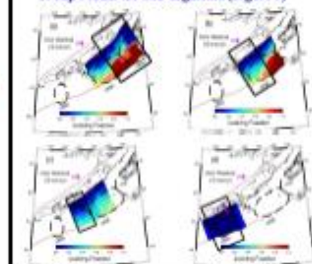
Figure 6. The location of poles for all the blocks in this study. The red solid and dashed lines are showing the block boundaries. The purple rectangle shows the study area. New estimated pole of PENN block is using GPS sites within the Alaska Peninsula and eastern Aleutians.

3. Results

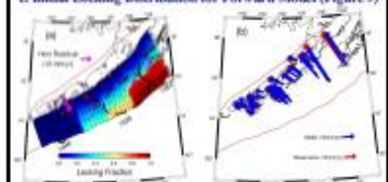
a. Inconsistency between Horizontal and Vertical Velocities (Figure 7)



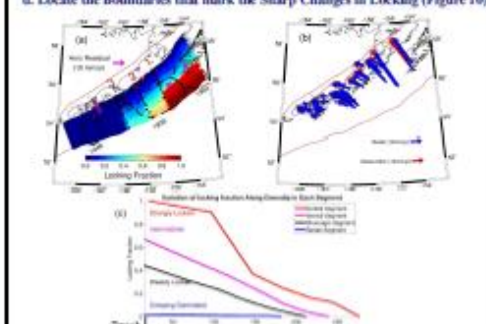
b. Slip Model for Sub-segments (Figure 8)



c. Initial Locking Distribution for Forward Model (Figure 9)

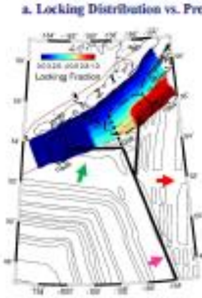


d. Locate the Boundaries that mark the Sharp Changes in Locking (Figure 10)



4. Correlation between Locking Distribution and Plate Fabric from Magnetic Anomaly, and Subduction Seismicity

a. Locking Distribution vs. Pre-existing Fabric



Boundary 1:

correlates with the change in pre-existing plate fabric due to the cessation of the Kula-Pacific spreading (intermediate locked) and beginning of the Vancouver-Pacific spreading (strong locked).

Boundary 2:

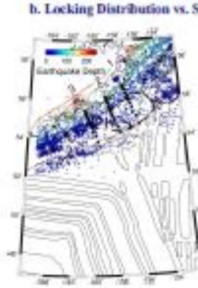
correlates with the change in pre-existing plate fabric where the northern portion of the Farallon plate broke off and became the Vancouver plate with a new spreading direction.

Boundary 3:

correlates with a major orientation change in two younger sections of pre-existing seafloor fabric indicated by the magnetic anomalies near the trench.

Figure 11. Digital Magnetic Anomaly polygons provided by Peter Haeussler and Keith Labay [Origin: Atwater 1989; Atwater and Severinghaus, 1989]

b. Locking Distribution vs. Subduction Seismicity



Shallow earthquakes:

More common in the creeping dominated area and near trench in the strongly locked area, less common in the weakly coupled and intermediate area.

Outer-rise earthquakes:

More abundant in the creeping dominated area than in the other three locked areas.

Intermediate depth earthquakes:

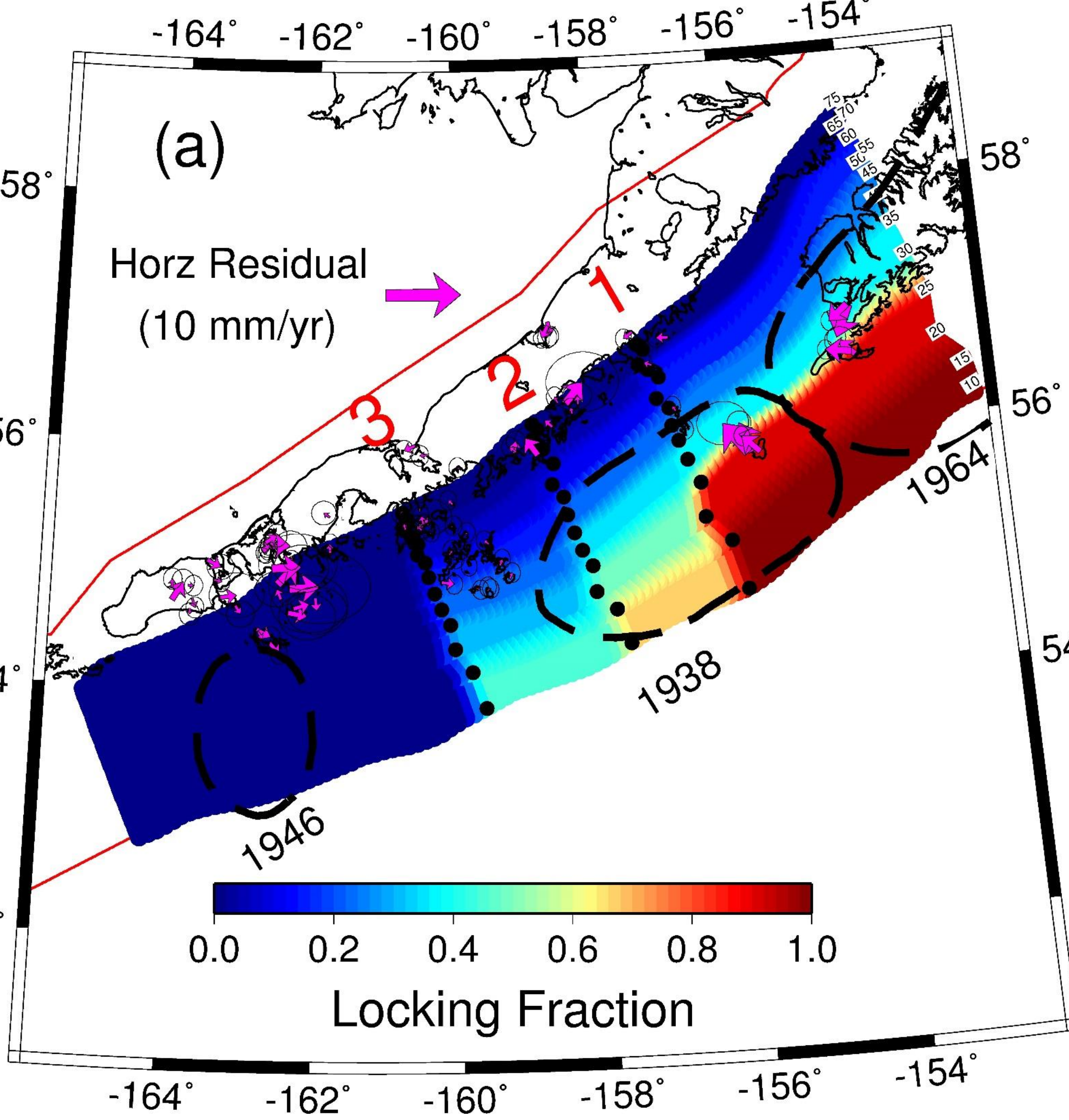
More in the creeping dominated area and in the strongly locked area, then less in between.

Figure 12. Seismicity (Magnitude > 3.0) from the Alaska Earthquake Center from 1990 to present.

5. Conclusion

6. References

7. Acknowledgement


(a)
Horz Residual
(10 mm/yr)
1
2
3
1964
1938
1946
0.0
0.2
0.4
0.6
0.8
1.0
Locking Fraction
-164°
-162°
-160°
-158°
-156°
-154°
58°
56°
54°
52°