

A scenic landscape of a fjord in Alaska. The image shows a calm body of water in the foreground, reflecting the sky and the surrounding mountains. The mountains are rugged and dark, with some snow or ice patches. The sky is a deep blue with scattered white and orange-tinted clouds, suggesting a sunset or sunrise. The overall mood is serene and majestic.

Alaska

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Big, Fast, Spatial Variations

- **BIG** earthquakes, volcanoes, glaciers, etc
- **FAST** rates of processes.
- **SPATIAL VARIATIONS** in *inputs* (subduction obliquity, sediment in trench, hydration of downgoing plate) and *outcomes* (interseismic slip deficit, seismicity in slab, creep behavior, volume flux and chemistry of magmatism)
- A high signal to noise ratio environment

Key Advantages of Alaska

- **Faulting and Earthquake Cycles:** Large and great earthquakes within the instrumental record and likely in the future
 - We have quantitative information about patterns of coseismic and postseismic slip, interseismic creep/slip deficit, and slow slip events
- **Magmatic Drivers of Eruption:** Eruptions at a wide variety of scales, highly varied volcanic behavior
- **Landscapes & Seascapes:** Although sparsely studied, there are many landslides, rapid erosion and exhumation, large amounts of sediment mobilized.

Earthquakes and Tectonics

Earthquakes in Alaska

U.S. DEPARTMENT OF THE INTERIOR
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Pre-1964 Earthquakes
Post-1964 Earthquakes
Earthquake Magnitude

- 6.0 - 6.9
- 7.0 - 7.9
- 8.0 - 8.4
- 8.5 - 8.9
- 9.0 or larger

1964 Earthquake rupture zone and date of most recent rupture

Active and potentially active faults

Earthquake risk is high in much of the southern half of Alaska, but it is not the same everywhere. This map shows the overall geologic setting in Alaska that produces earthquakes. The Pacific plate (darker blue) is sliding northwestward past southern Alaska and then dives beneath the North American plate (light blue, green, and brown) in southern Alaska, the Alaska Peninsula, and the Aleutian Islands. Most earthquakes are produced where these two plates come into contact and slide past each other. Major earthquakes also occur throughout much of interior Alaska as a result of collision of a piece of crust with the southern margin.

A fault beneath a fold in Cook Inlet resulted in a magnitude 7 earthquake in 1933 that strongly shook Anchorage.

The 1964 earthquake was the second largest ever recorded in the world. The area within this pink patch slipped seaward up to 66 feet.

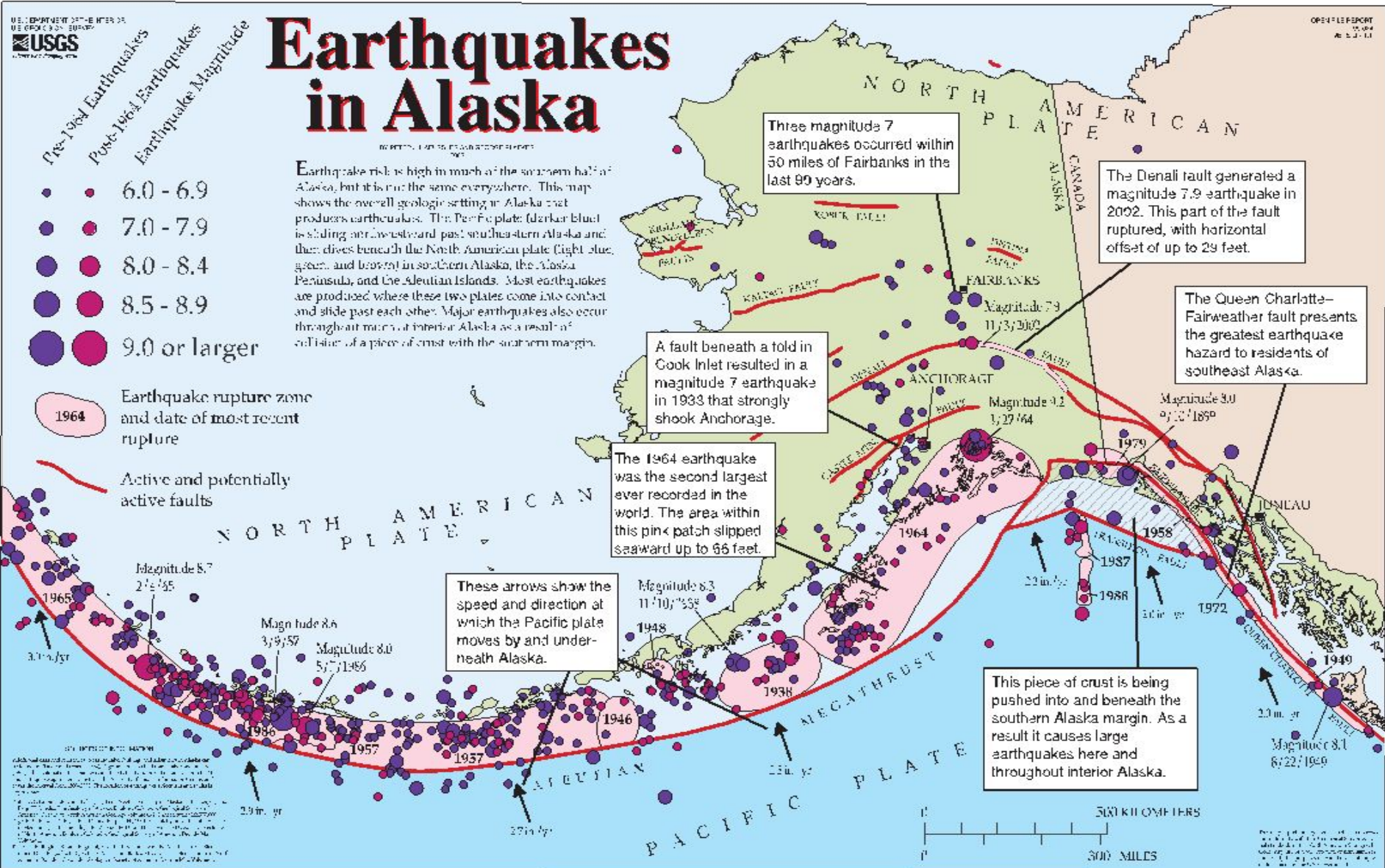
These arrows show the speed and direction at which the Pacific plate moves by and underneath Alaska.

Three magnitude 7 earthquakes occurred within 50 miles of Fairbanks in the last 90 years.

The Denali fault generated a magnitude 7.9 earthquake in 2002. This part of the fault ruptured, with horizontal offset of up to 29 feet.

The Queen Charlotte-Fairweather fault presents the greatest earthquake hazard to residents of southeast Alaska.

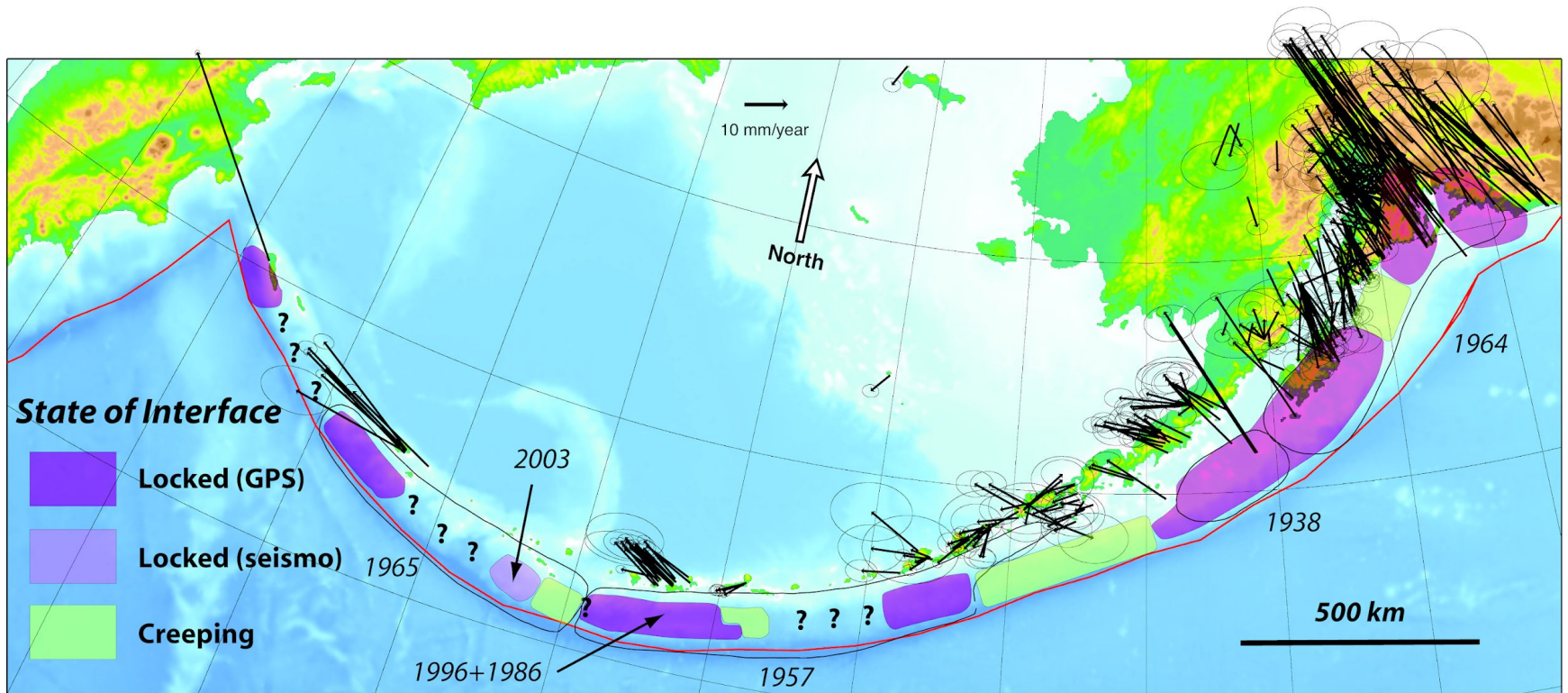
This piece of crust is being pushed into and beneath the southern Alaska margin. As a result it causes large earthquakes here and throughout interior Alaska.



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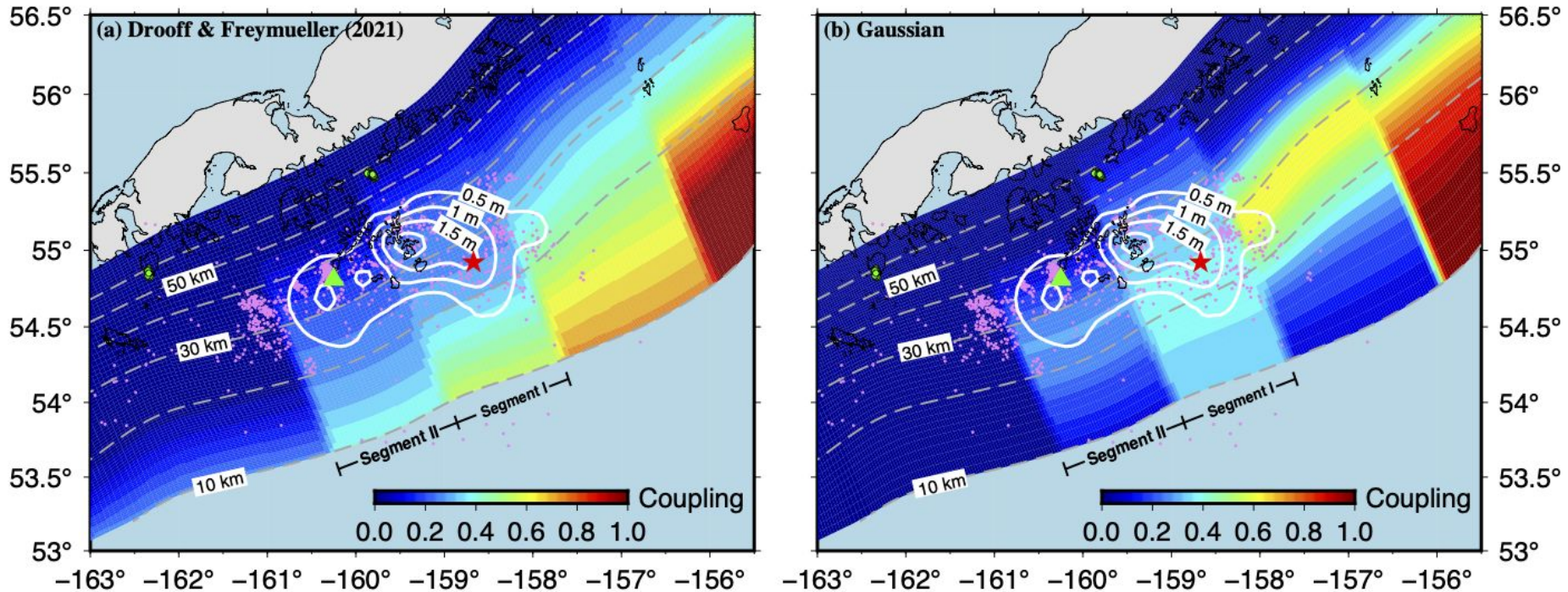
OPEN-FILE REPORT
15-04
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Interseismic Slip Deficit Constraints



Simeonof Earthquake (July 2020)

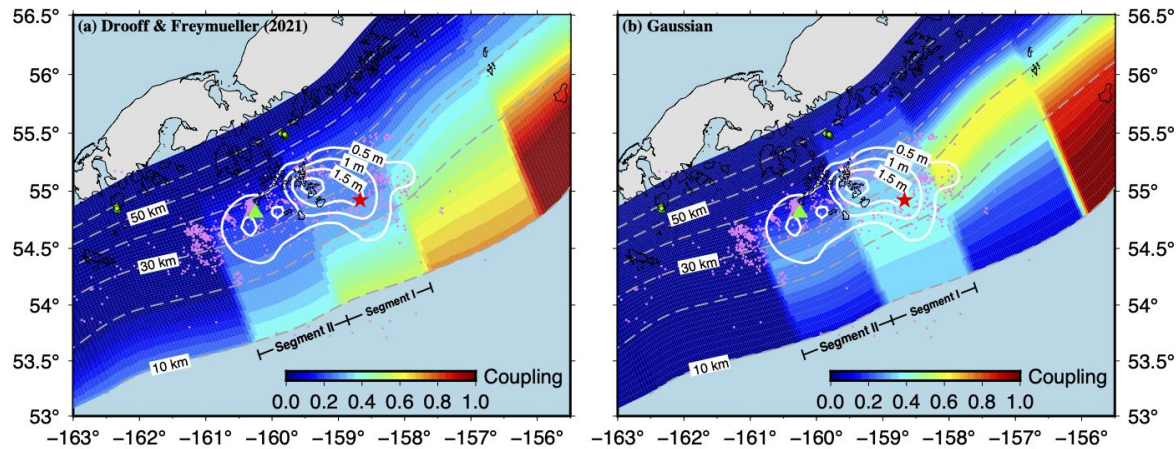
M7.8 megathrust earthquake



Coseismic slip did appear to change at the interseismic segment boundaries

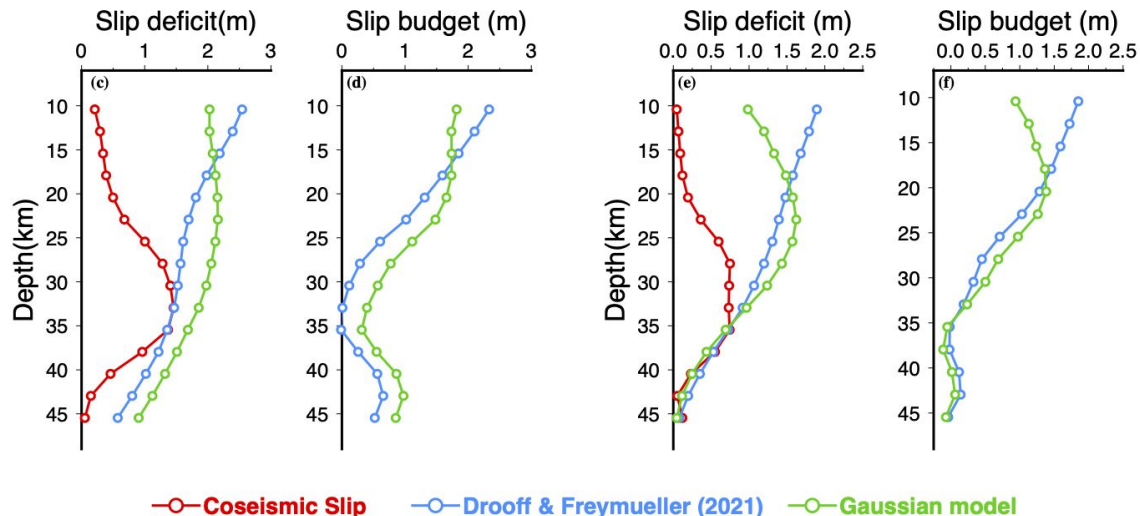
Simeonof Earthquake (July 2020)

Slip Budget



Segment I

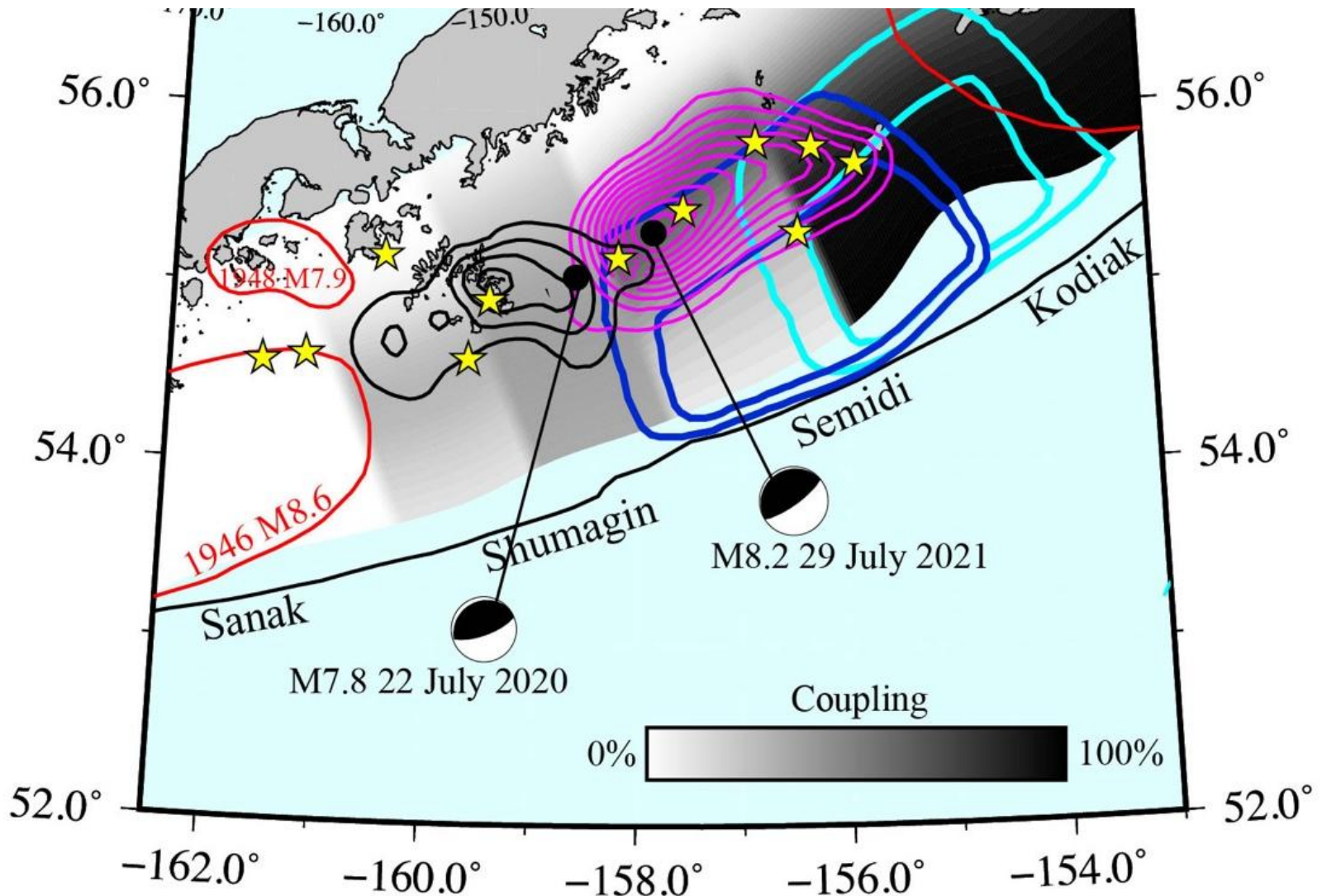
Segment II



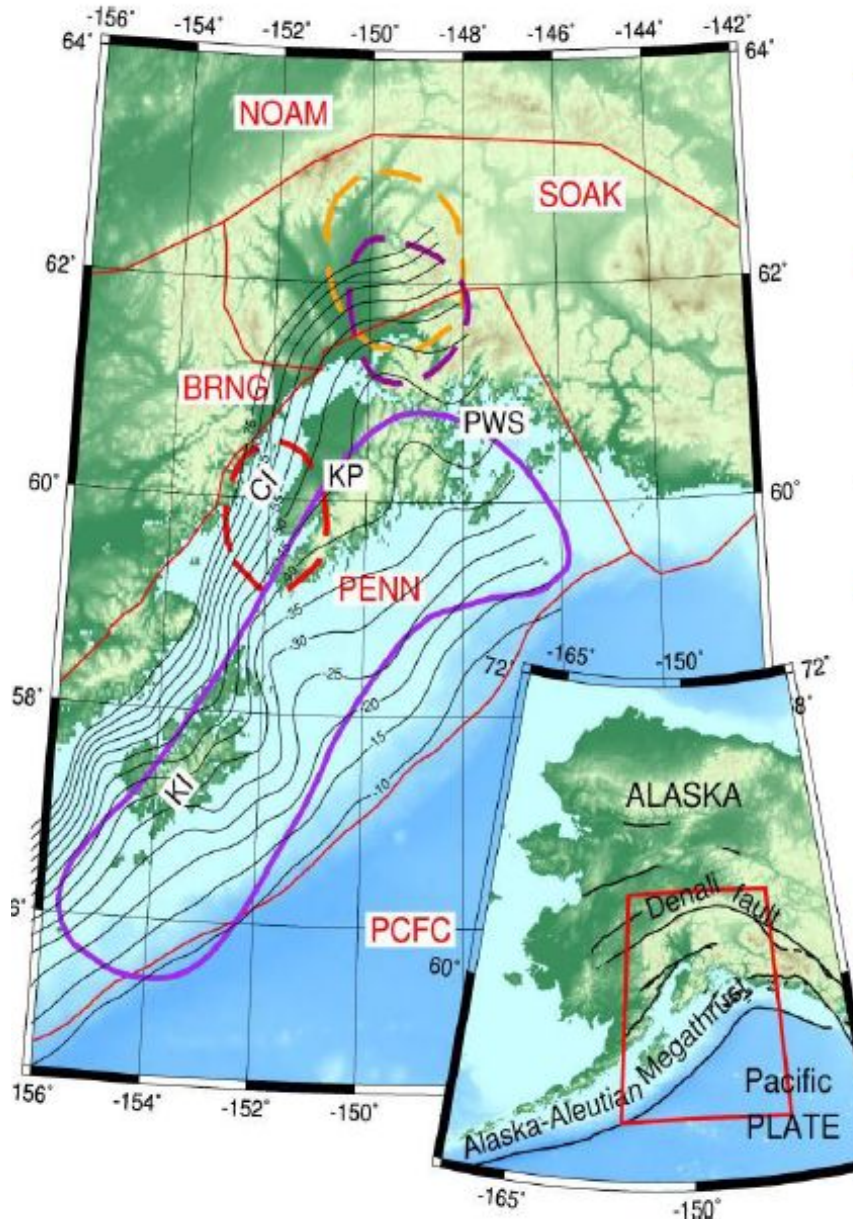
- All slip deficit released below ~30 km

- Room for a similar-sized earthquake shallower

2020-2021 and 1938



Slow Slip Events



- Multiple slow slip events have been observed downdip of the 1964 earthquake (M9.3) rupture zone.
- SSE durations 2-9+ years.
- Equivalent magnitudes as large as M7.8
- Other segments appear to have a lack of SSEs

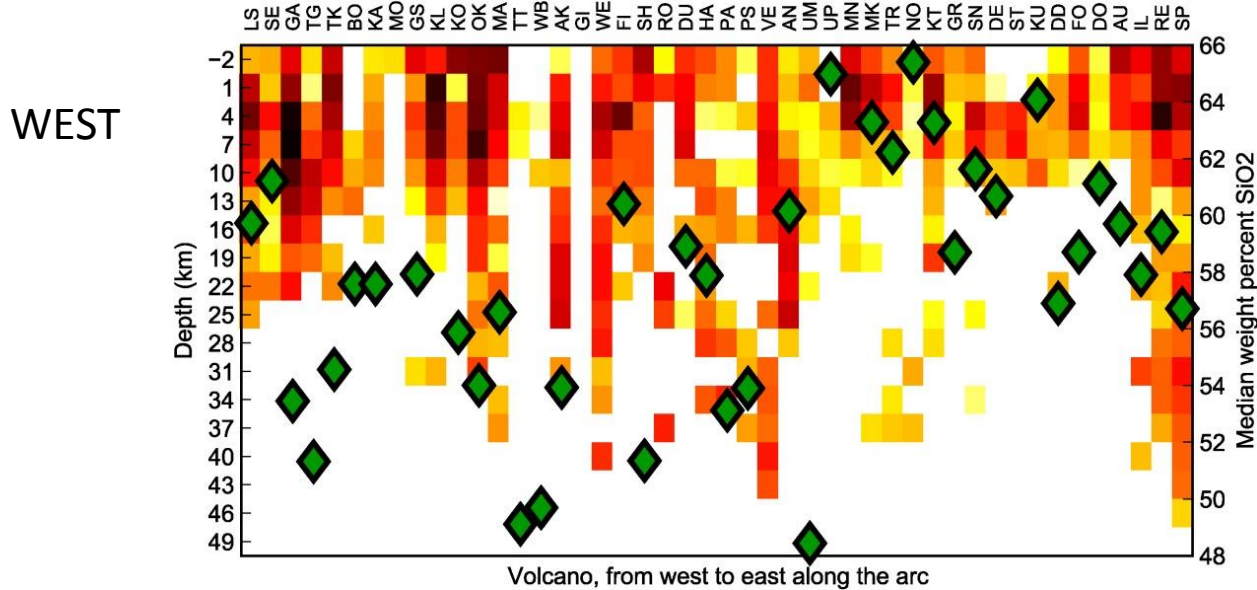
Eruptive Volcanism



- Roughly 2 eruptions/year, plus a few per year showing unrest
- “Open system” volcanoes such as Pavlof, Cleveland
- Large calderas (e.g., Aniakchak, Fisher, Okmok), many of which were ~size of Mt. Veniaminof (~20-25 km diameter at base, ~2500 m)

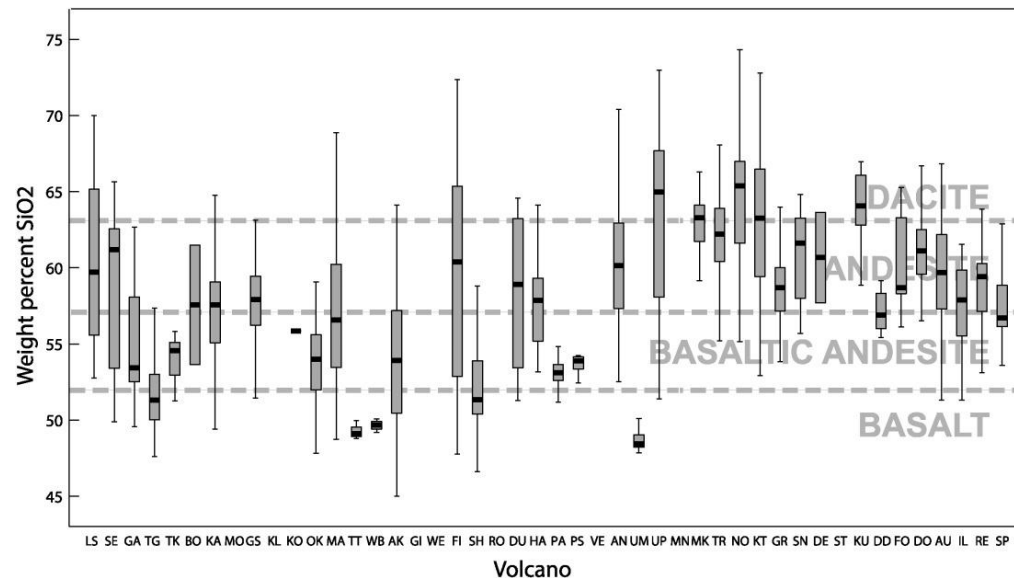
USGS Photo (Augustine)

Variation in Seismicity, Chemistry



EAST

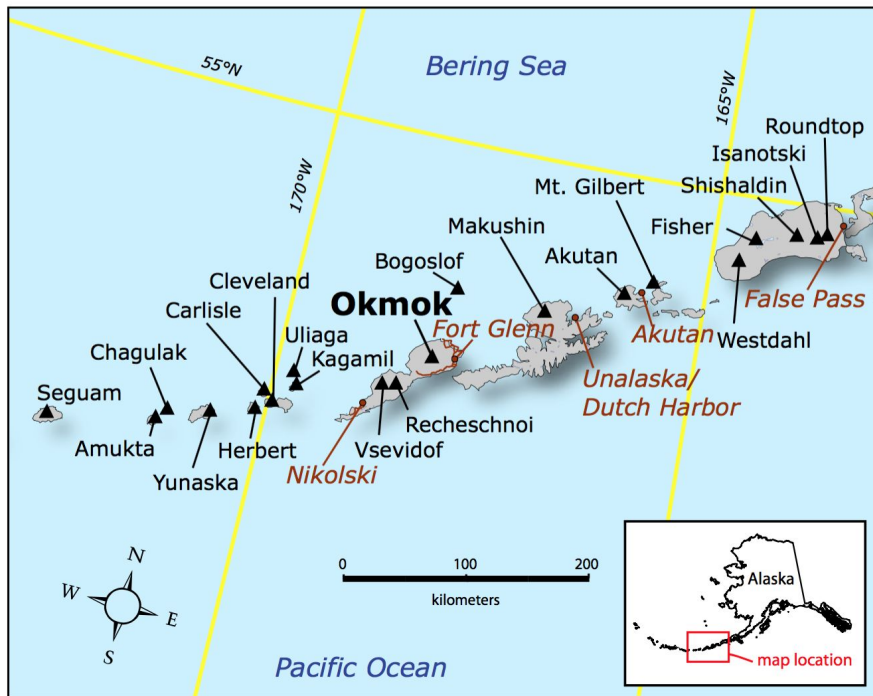
- The depth of volcanic earthquakes varies systematically along the Aleutian arc
- Volcanic earthquake depths and SiO₂ show similar along-arc trends
- Regional subduction processes control volcanic activity



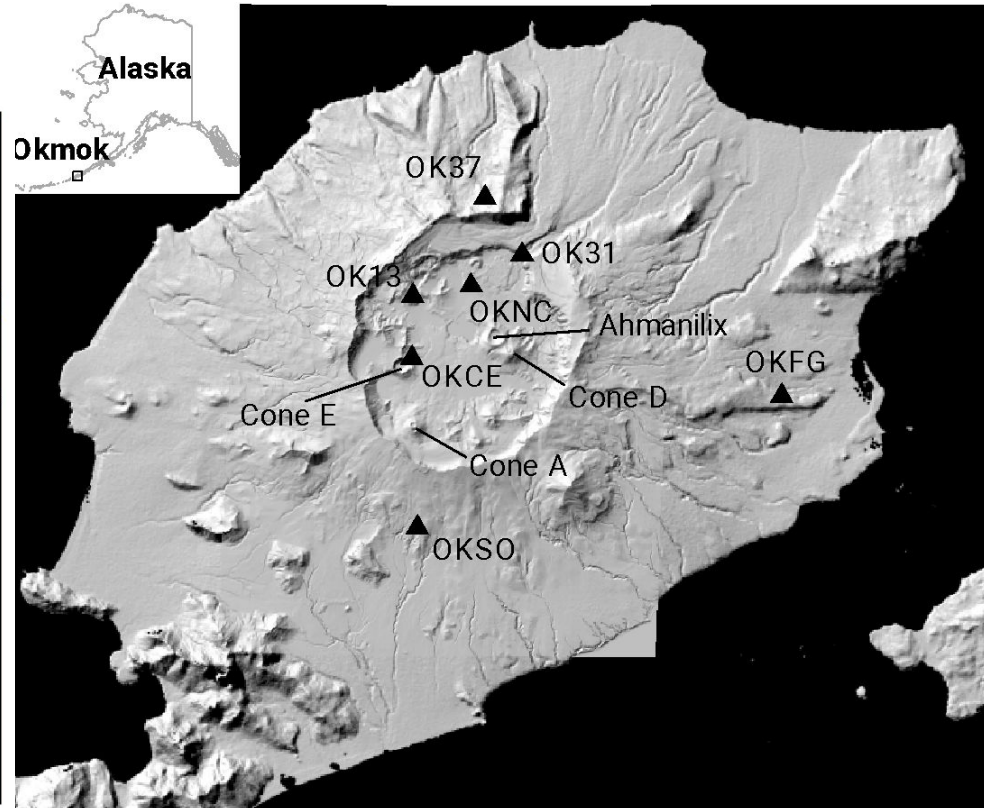
Eruptions 2005-2021

CLEVELAND	VENIAMINOF	PAVLOF	SHISHALDIN	GREAT SITKIN
🚫 2005	🚫 2005	🚫 2007	🌟 2008	🌟 2017
🚫 2006	🚫 2005	🚫 2013	🌟 2008	🚫 2018
🚫 2007	🚫 2006	🚫 2014	🌟 2009	🌟 2019
🚫 2009	🚫 2008	🚫 2014	🚫 2014	🚫 2021
🚫 2009	🚫 2009	🚫 2016	🚫 2019	
🚫 2010	🚫 2013	🚫 2021		SEMISOPOCHNOI
🌟 2010	🚫 2018			🚫 2018
🚫 2011	🚫 2021			🚫 2019
🚫 2013				🚫 2021
🚫 2014	AUGUSTINE	ATKA VOLCANIC COMPLEX	FOURPEAKED	OKMOK
🚫 2016	🚫 2005	🌟 2005	🚫 2006	🚫 2008
🚫 2016				
🚫 2017			KASATOCHI	REDOUBT
🚫 2019			🚫 2008	🚫 2009
🚫 2020	KANAGA	BOGOSLOF		
	🚫 2012	🚫 2016		

Post-eruption deformation at Okmok volcano, Alaska



Larsen et al. 2015

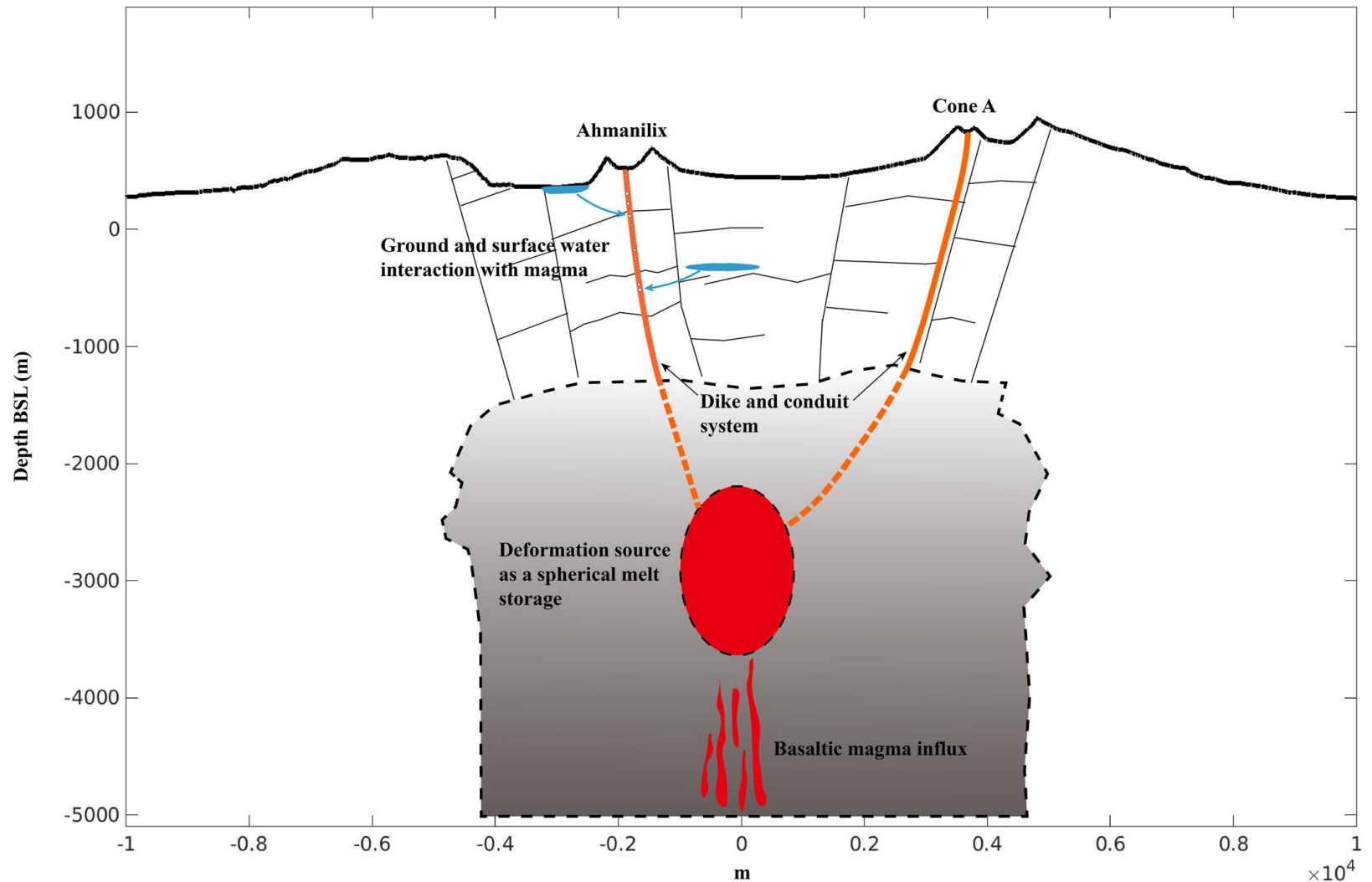


10 km

Okmok 2008 Eruption Deposits

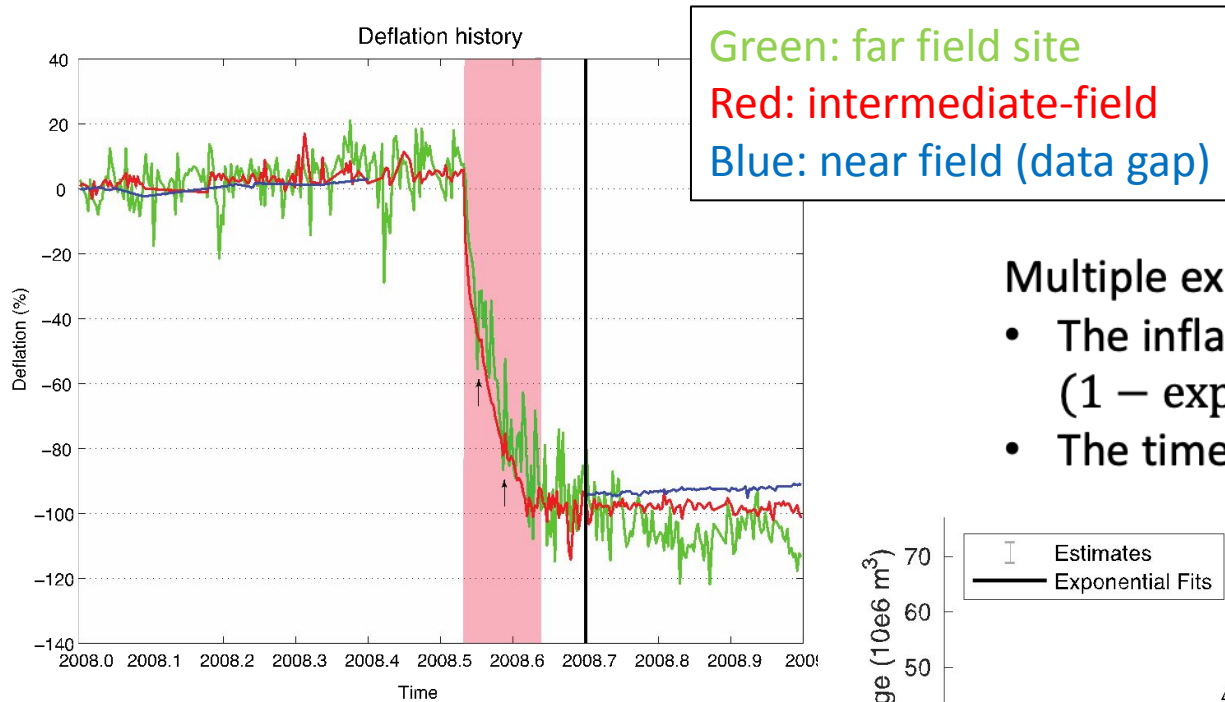


Okmok Interpreted Structure



Wang et al. (2021)

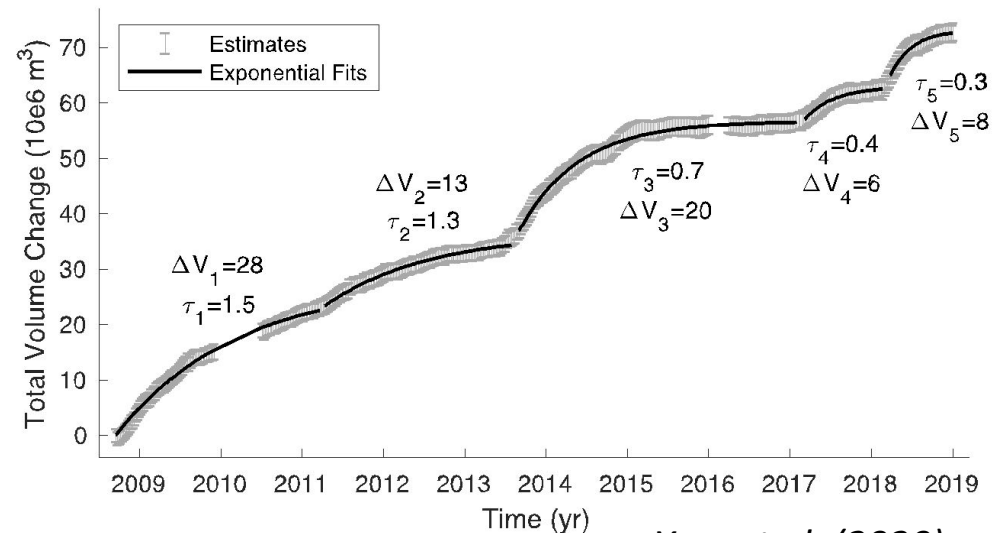
Okmok Deflation and Inflation



Freymueller and Kaufman (2010)

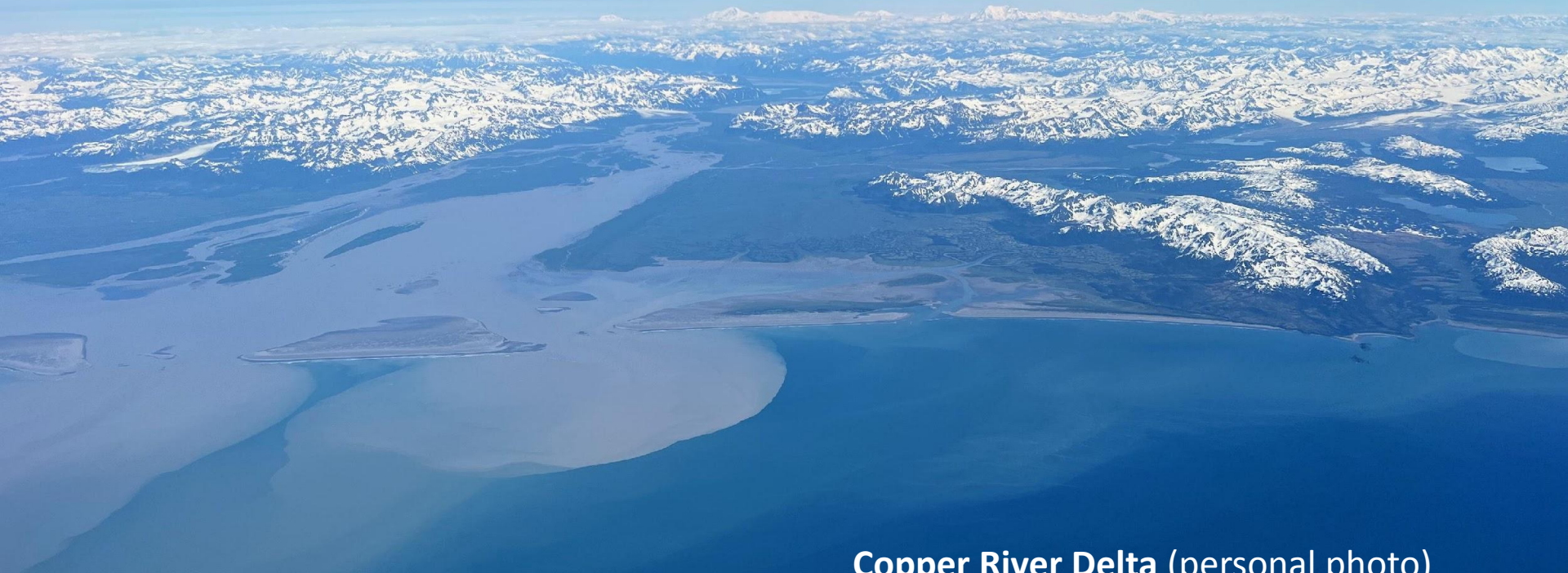
Multiple exponential inflation episodes.

- The inflation decays exponentially, $\Delta V \cdot (1 - \exp(-t/\tau))$
- The time scale τ decreases in time



Xue et al. (2020)

Landscape Processes

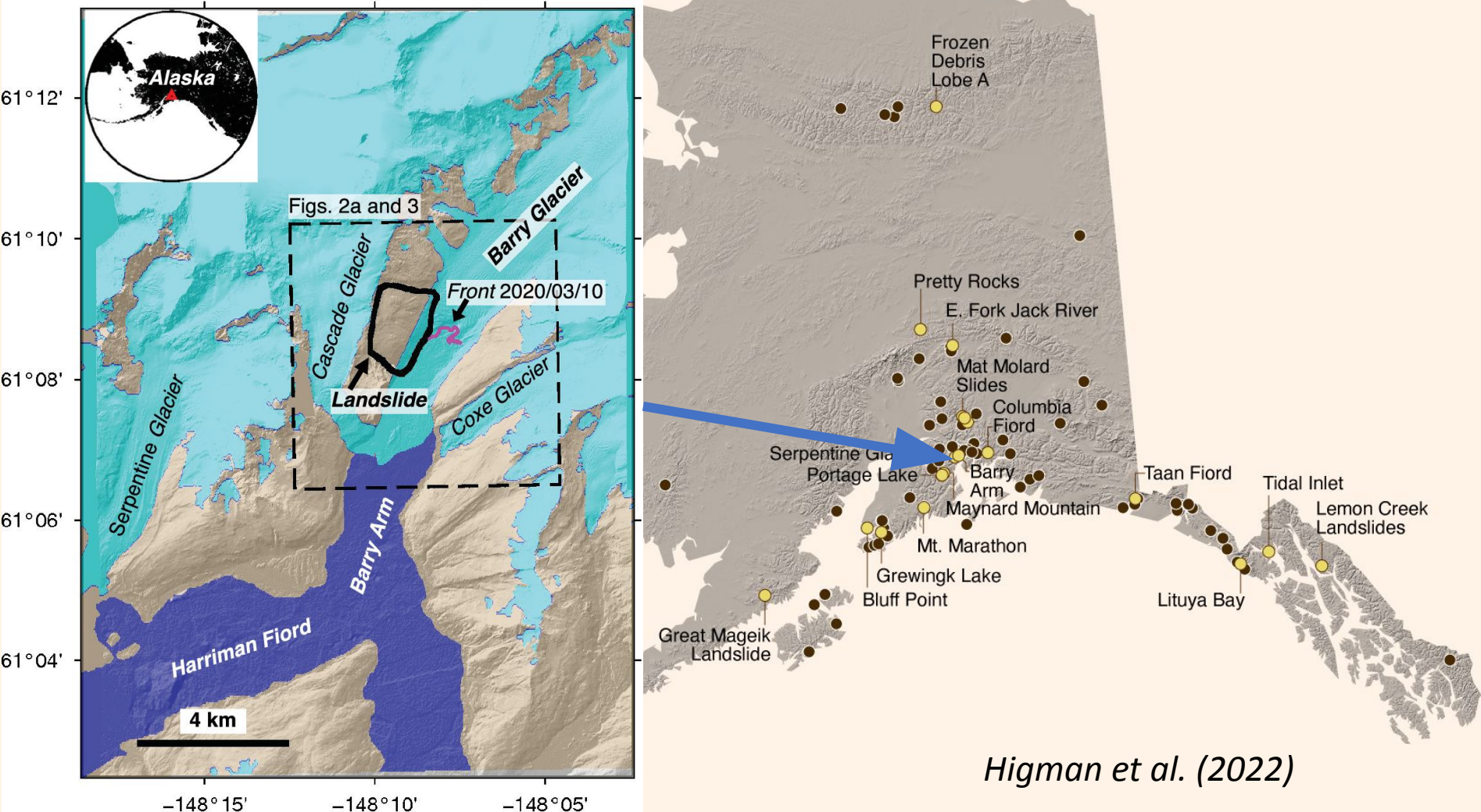


Copper River Delta (personal photo)
Suspended sediment load has been measured as high as 1800 mg/liter (e.g., Phalen, 2013), annual sediment load ~70 million tons.

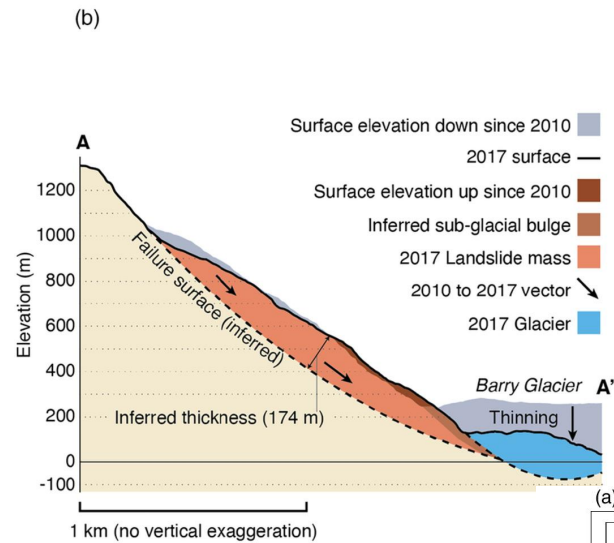
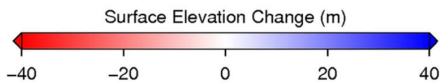
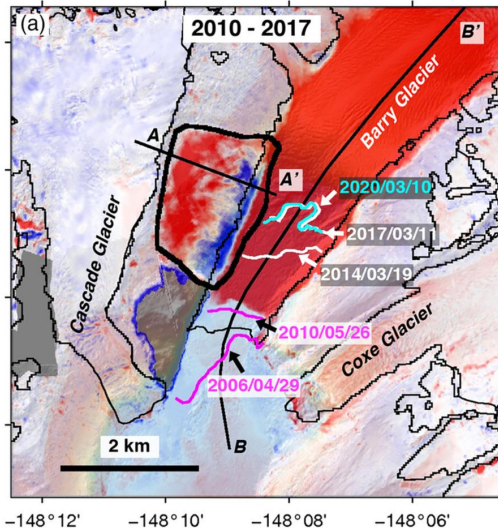
Large Landslides

100 Giant Alaska Landslides

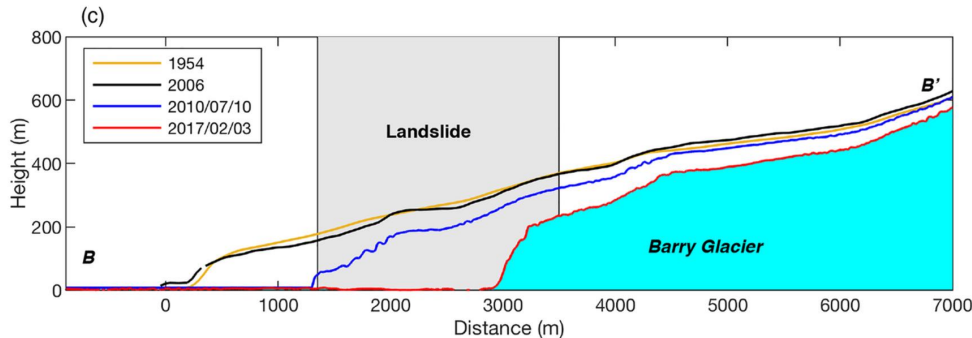
- Past, ongoing, or planned study sites
- Unstudied



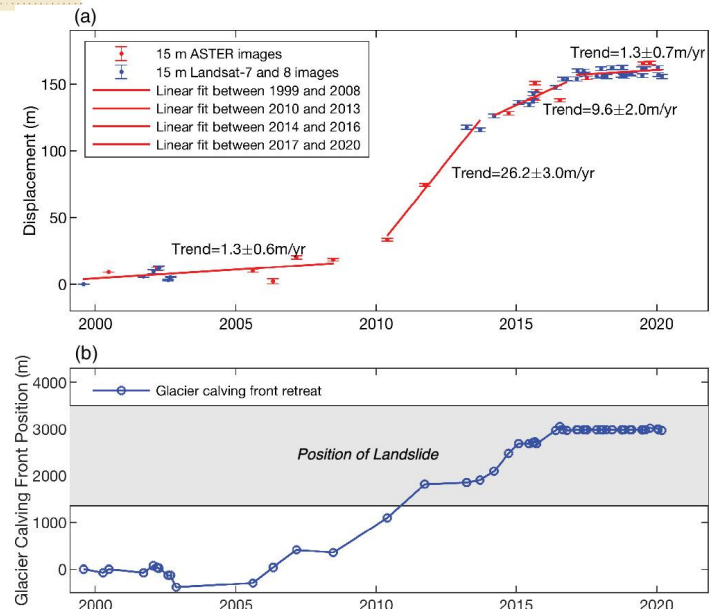
Barry Arm Landslide



- Landslide rapidly accelerated immediately after glacier retreated
- Now monitored due to hazard (possible tsunami), rate has varied since 2020



Dai et al. (2020)



Volcanic Sediment

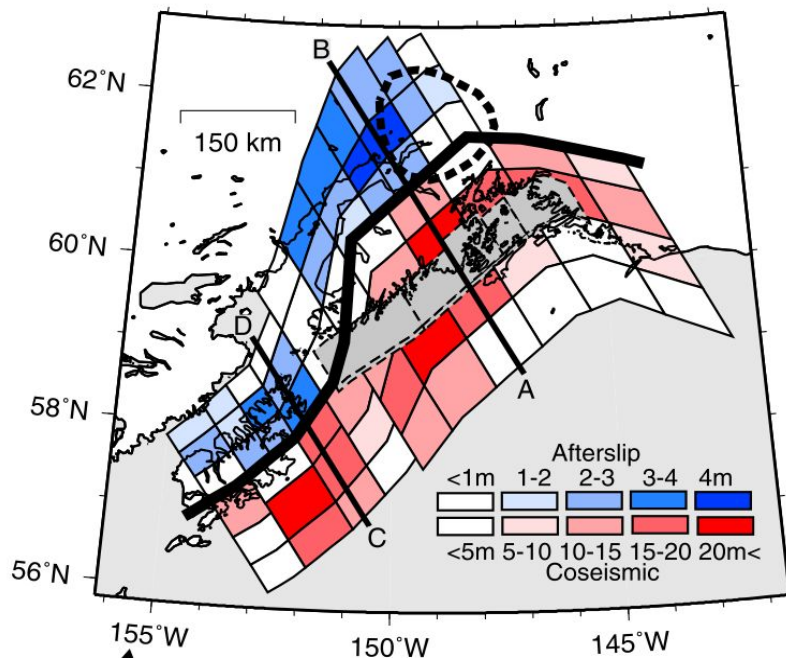


- Examples near Perryville, Alaska Peninsula
- Series of beach ridges
 - Large volumes of clastic volcanic sediments from Veniaminof Volcano

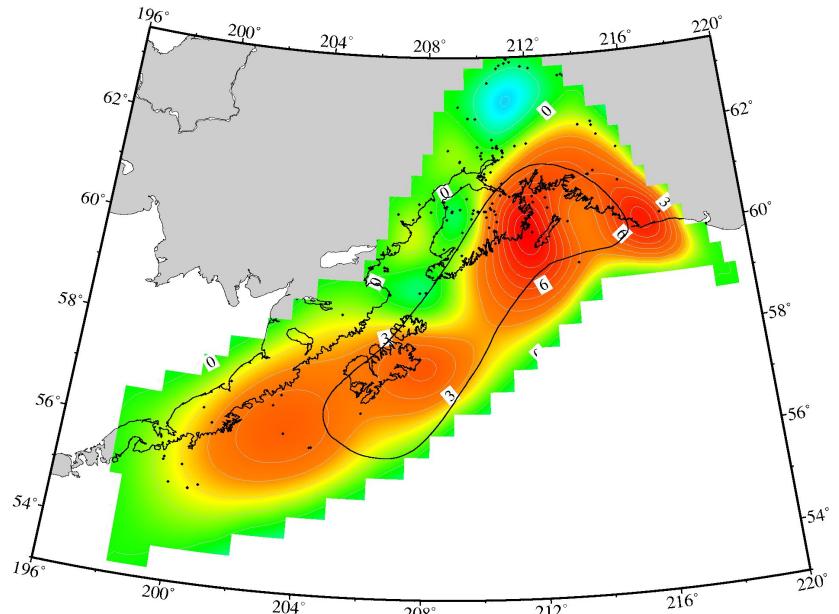
Any Time for Questions?

1964 Slip Models

Coseismic

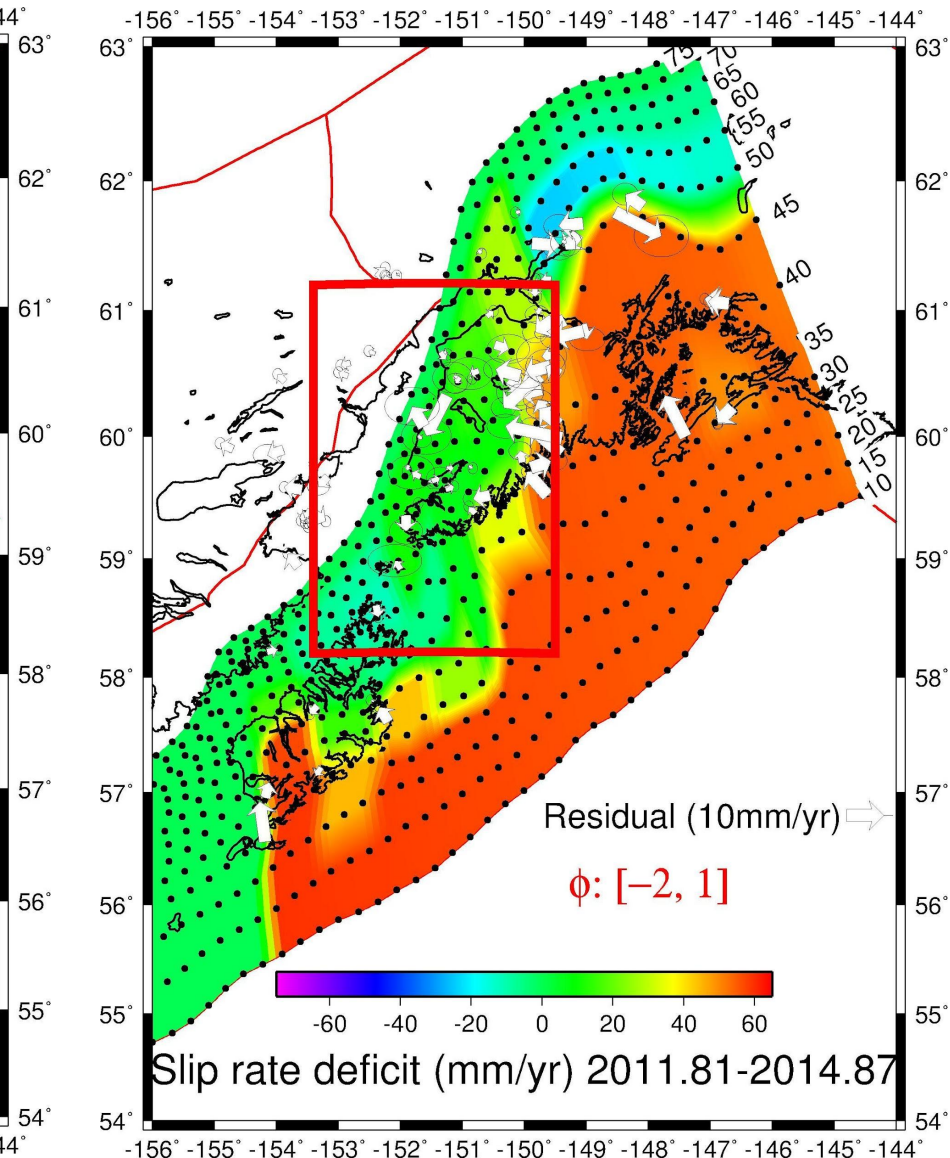
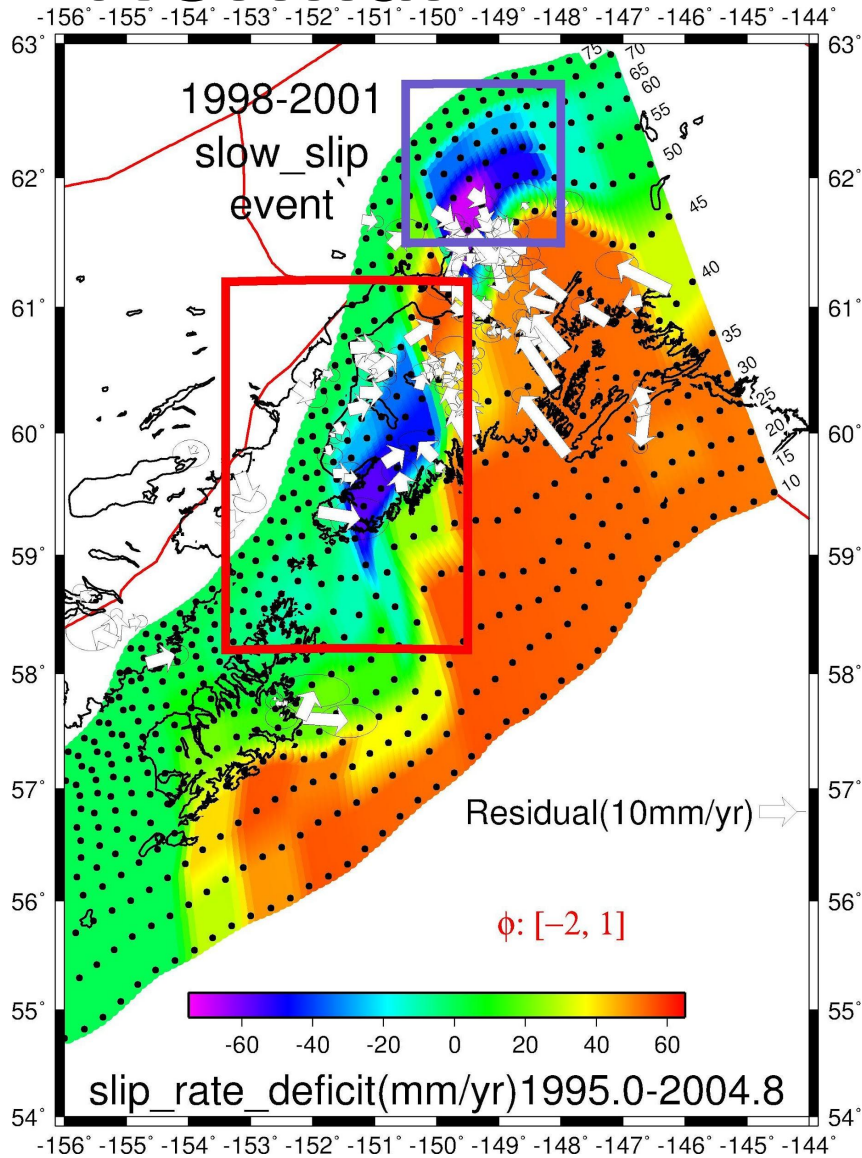


Present-day (interseismic)



Suito and Freymueller (2009)

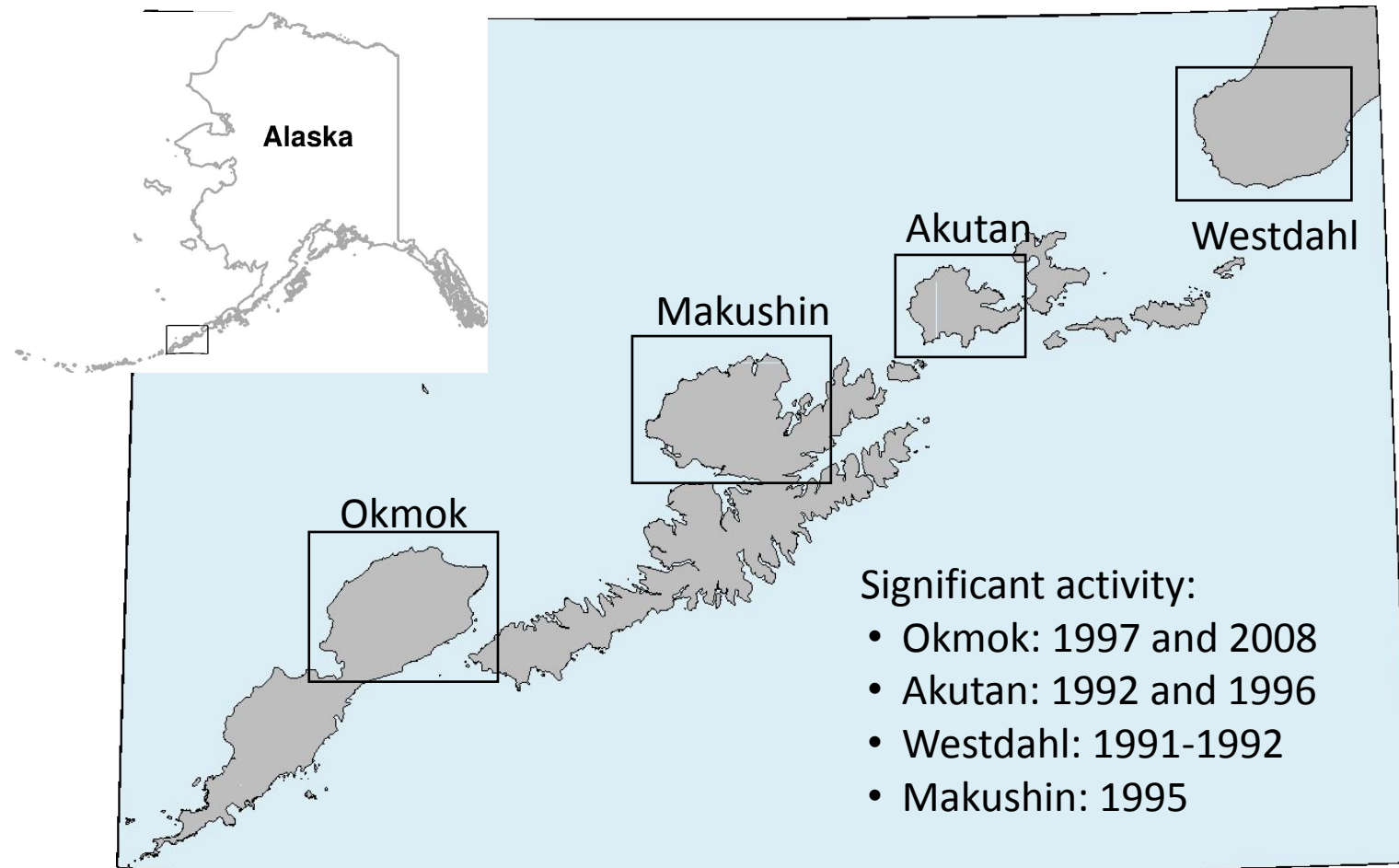
Slip Distribution of SSE vs Normal







Eastern Aleutian Arc



Xue et al. (2020)

Xue and Freymueller (2020)

Some Key Questions/Contradictions

- 1946 Tsunami earthquake