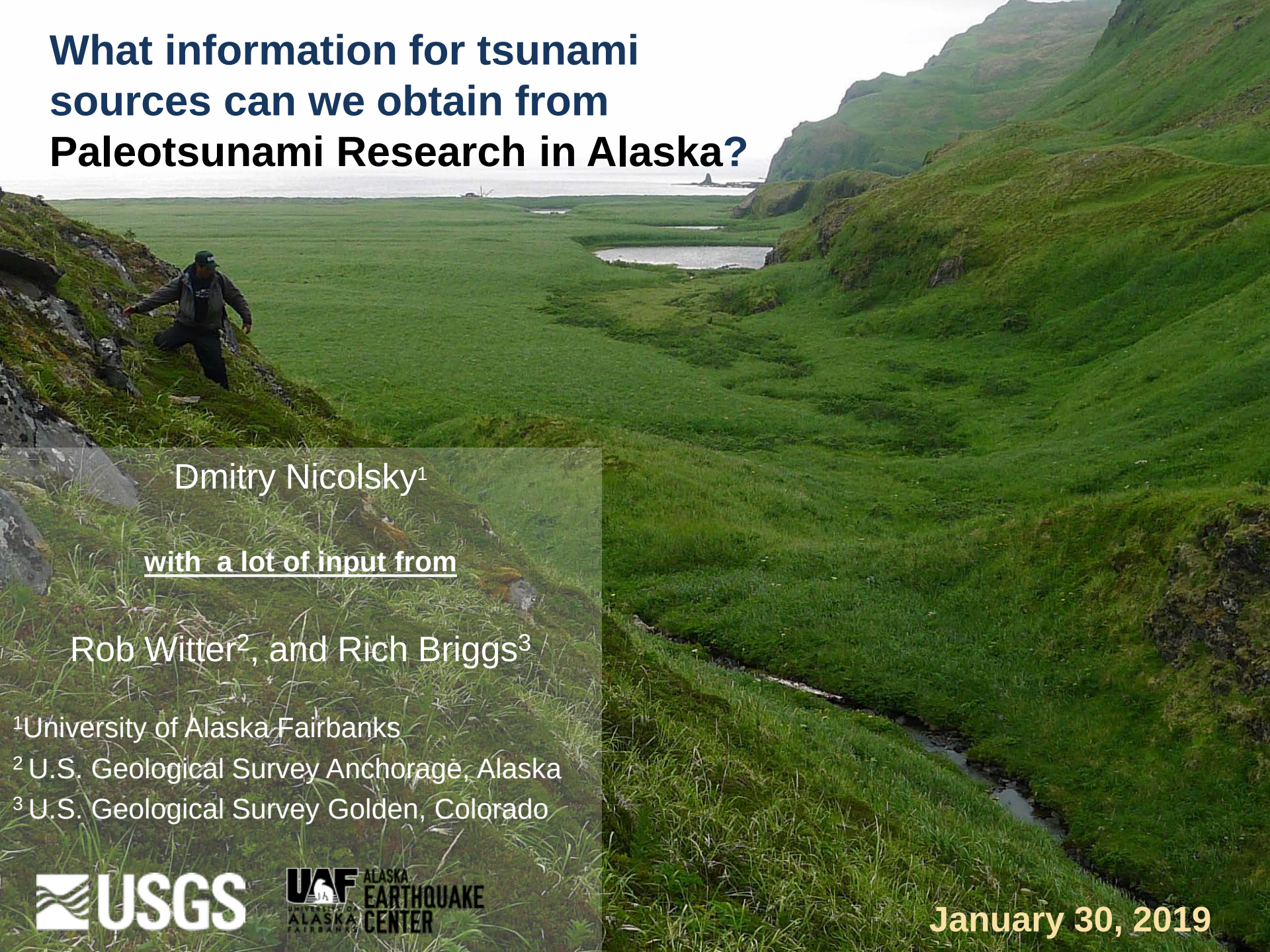
What information for tsunami sources can we obtain from Paleotsunami Research in Alaska?



Dmitry Nicolsky[1]

with a lot of input from

Rob Witter[2], and Rich Briggs[3]

[1]University of Alaska Fairbanks

[2] U.S. Geological Survey Anchorage, Alaska

[3] U.S. Geological Survey Golden, Colorado

USGS

UAF University of Alaska Fairbanks Alaska Earthquake Center

January 30, 2019

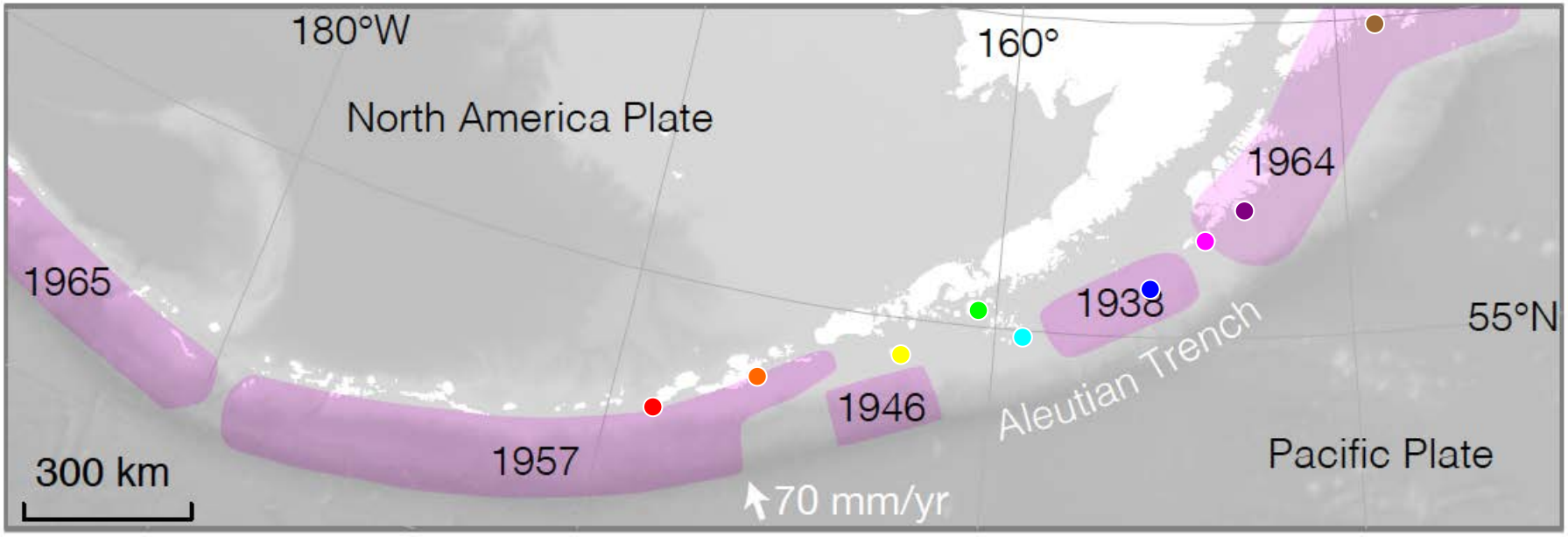

Sanak Island
2014


Sitkalidak Island
2015


Umnak Island
2013
USGS


Sitkinak Island
2011 and 2018

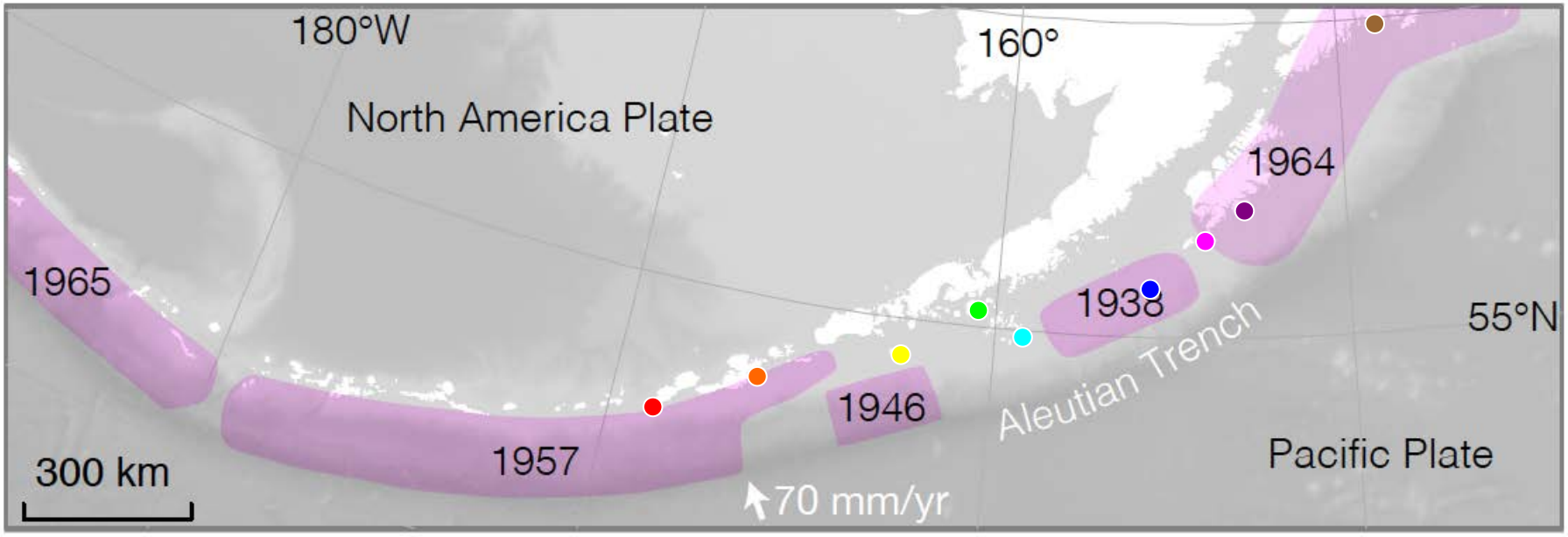
Field investigations along the Alaska-Aleutian subduction zone



Ten investigations from 2010–2018

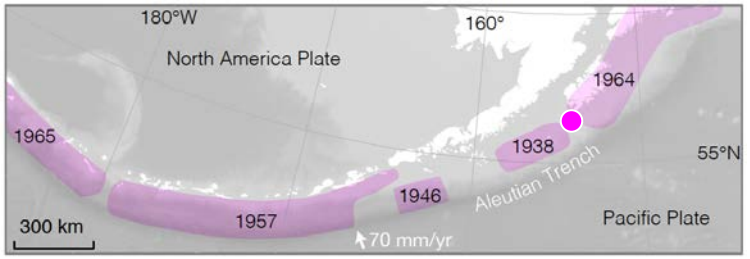
- Umnak Island
- Unga Island
- Sitkinak Island[2]
- Sedanka Island
- Simeonof Island
- Sitkalidak Island
- Sanak Island
- Chirikof Island
- Kenai Fjords

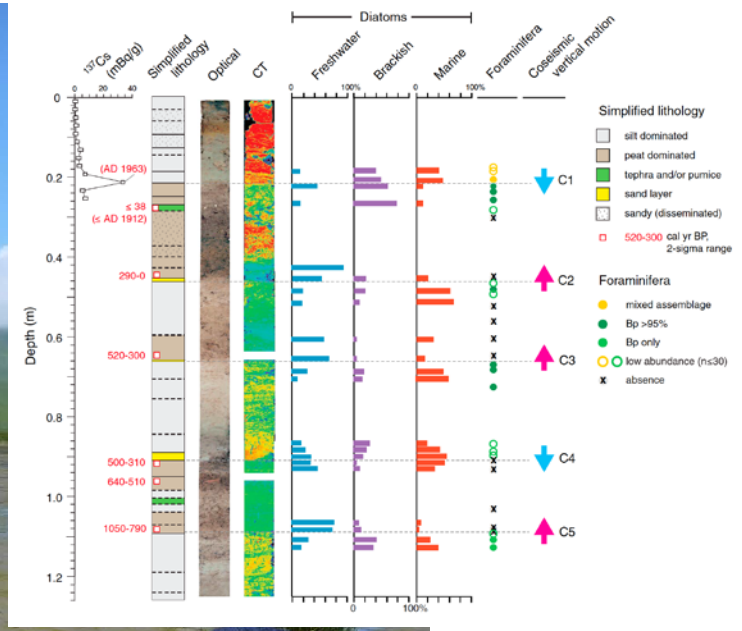
What information about Alaskan tsunami sources can we glean from field studies?



- *How persistent are rupture boundaries of historic earthquakes?*
- *How do field observations help define megathrust rupture patches?*
- *How often do great megathrust ruptures and tsunamis occur in the Aleutians?*

How persistent are rupture boundaries of historic earthquakes?



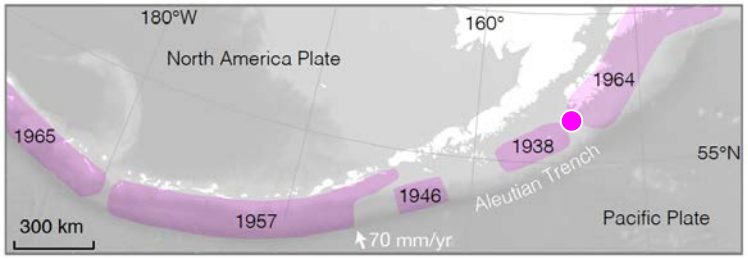


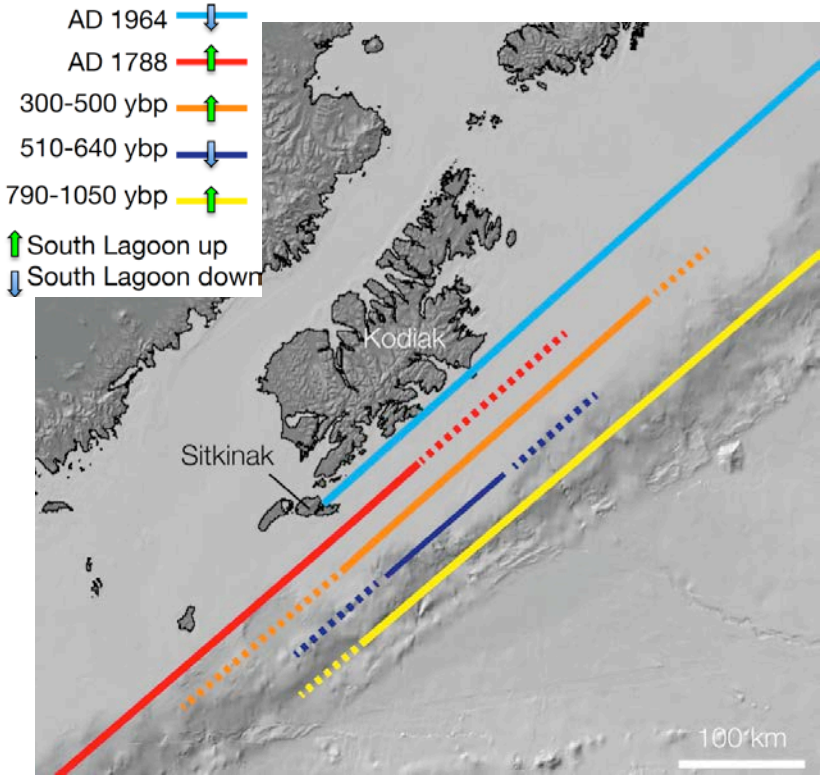
Briggs et al., 2014

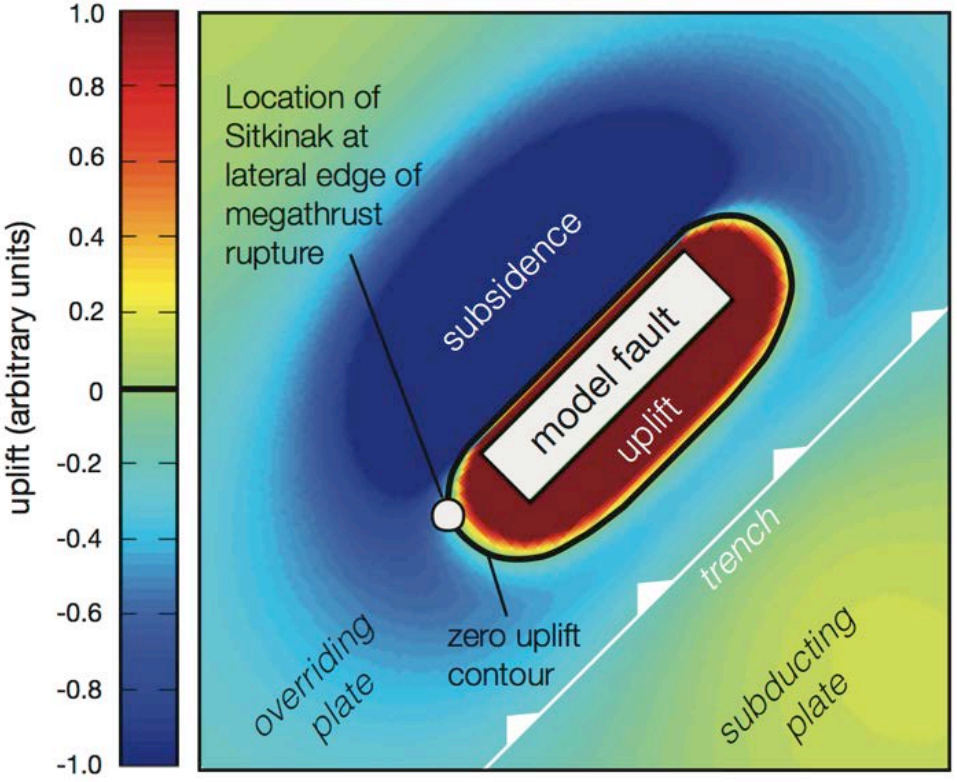
Resistant beds in saltmarsh

Sitkinak Island, Alaska

How persistent are rupture boundaries of historic earthquakes?

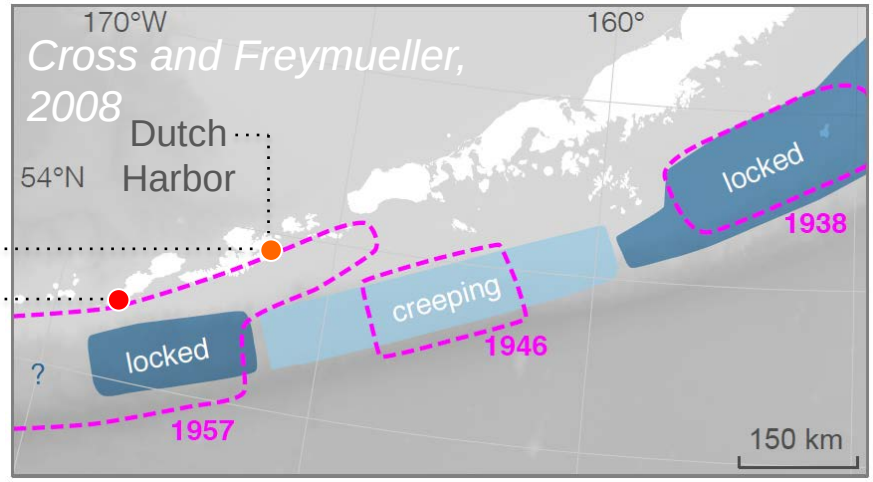






Briggs et al., 2014

How do field observations help define megathrust rupture patches?

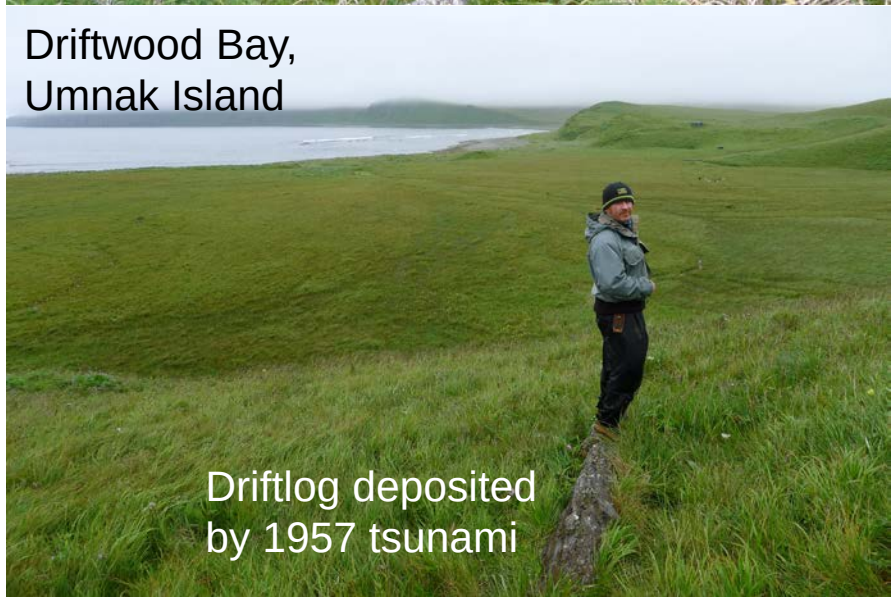


Fox Islands

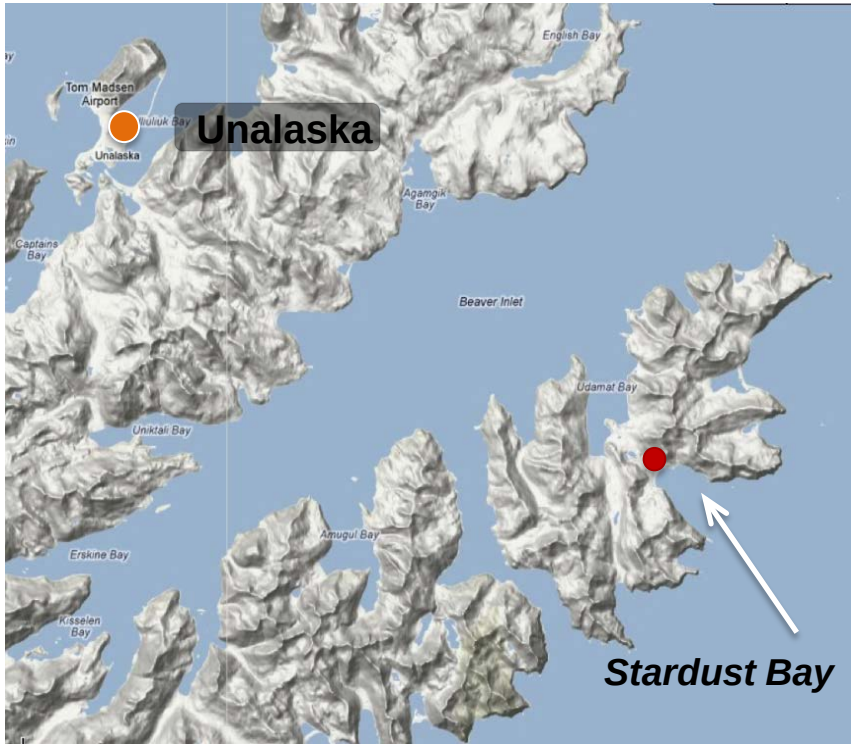
Unusually large tsunamis frequent a currently creeping part of the Aleutian megathrust.

(Witter et al., 2016, Nicolsky et al., 2016 Witter et al., 2018)

164–157 year recurrence



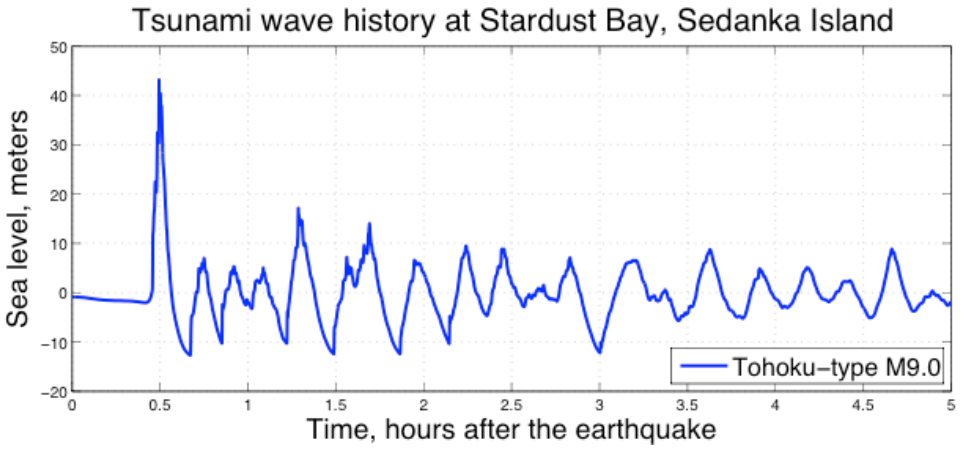
Stardust Bay



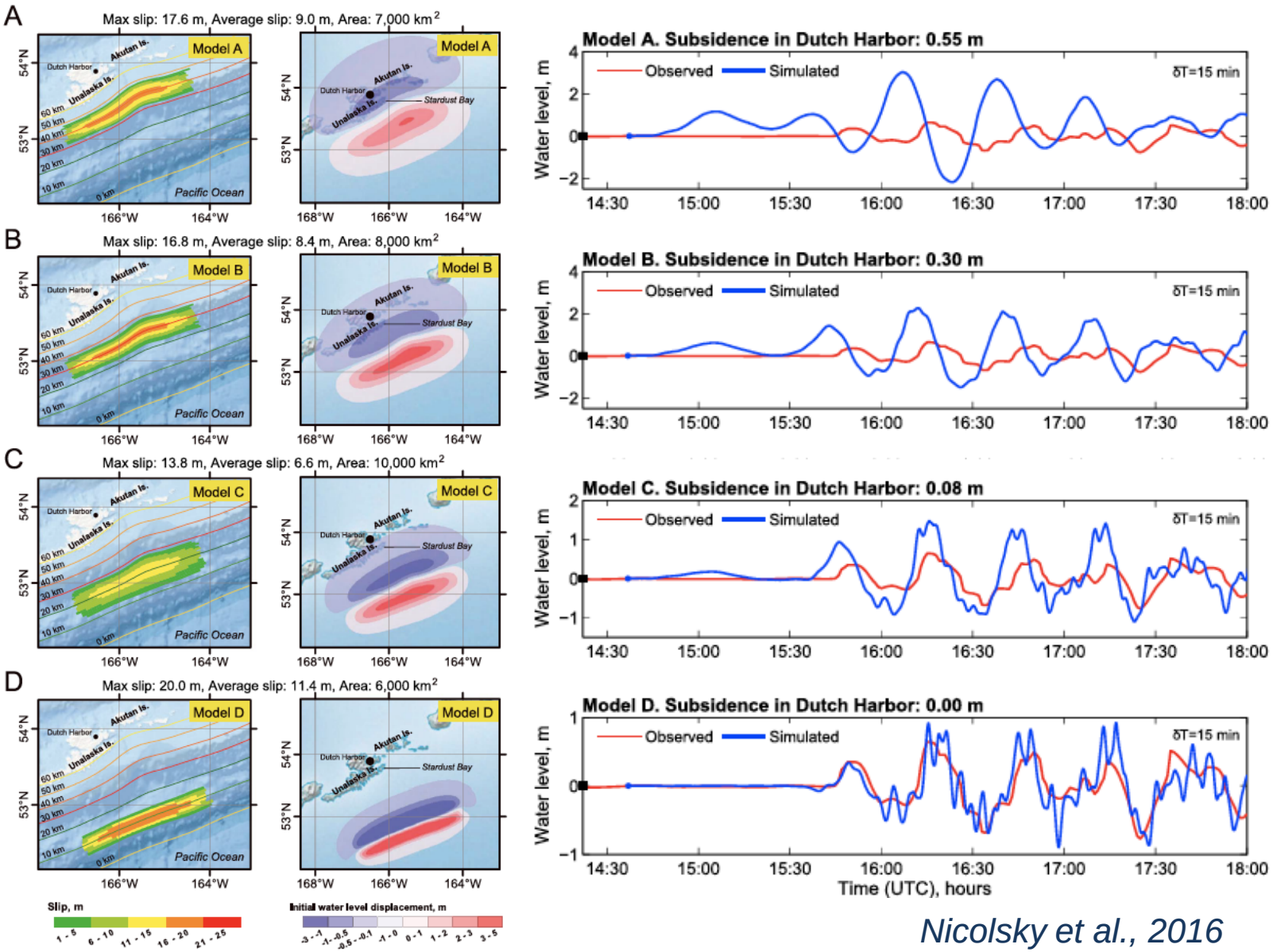
Witter, R.C., Carver, G.A., Bender, A., Briggs, R., Gelfenbaum, G., and Koehler, R.D., 2013**, Six large tsunamis in the past ~1700 years at Stardust Bay, Sedanka Island, Alaska.**

Inundation up to 18m (60ft) in 1957

- Analysis of the sediment core and runup data in Stardust Bay can be used to constrain the worst case tsunami scenarios.

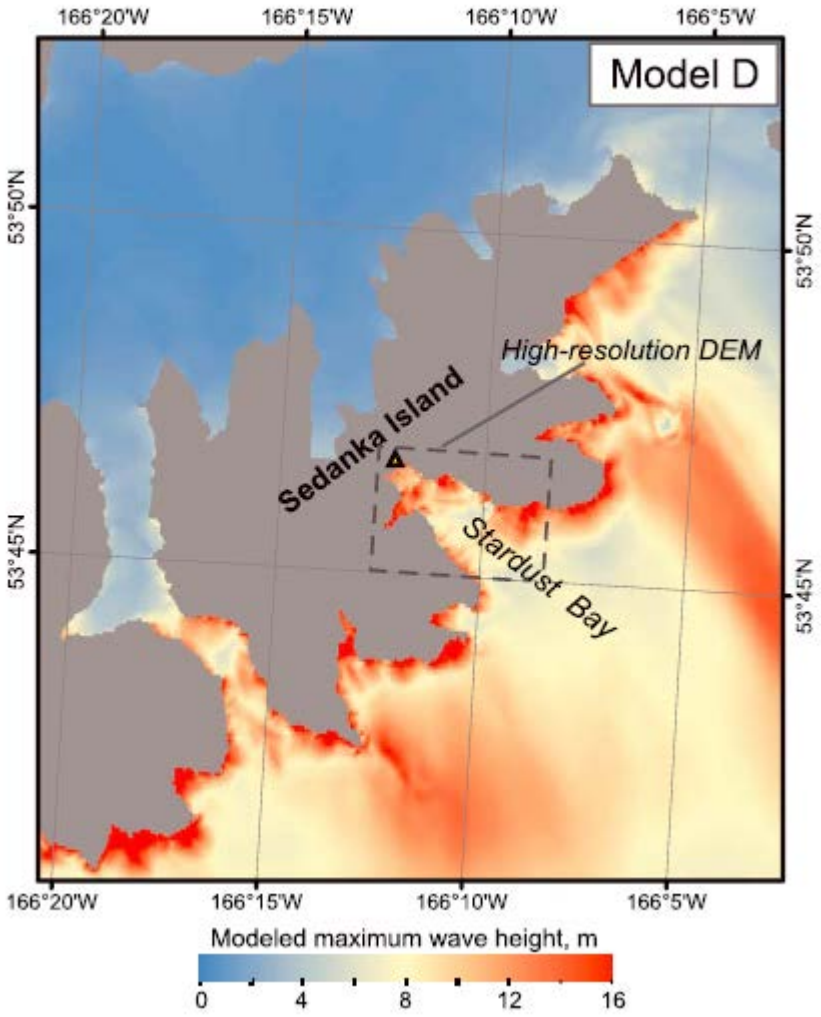


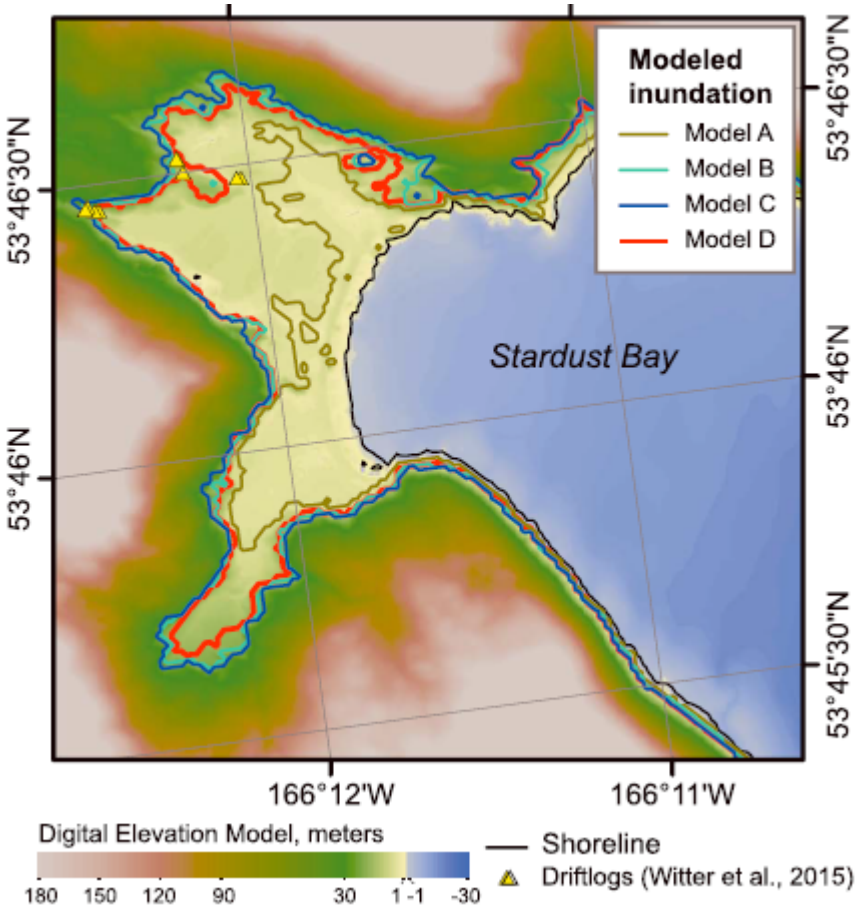
Tsunami models imply near-trench rupture in 1957



Nicolsky et al., 2016

Modeling runup of the 1957 tsunami at Stardust Bay

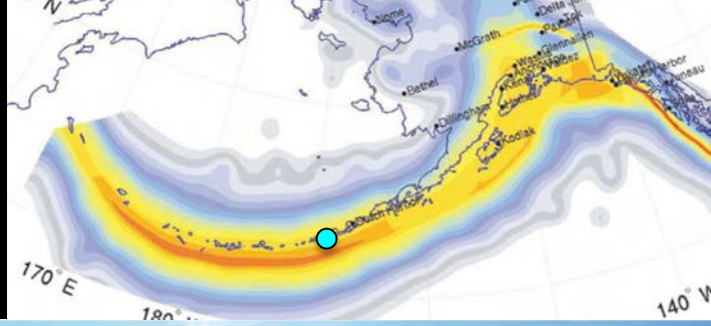


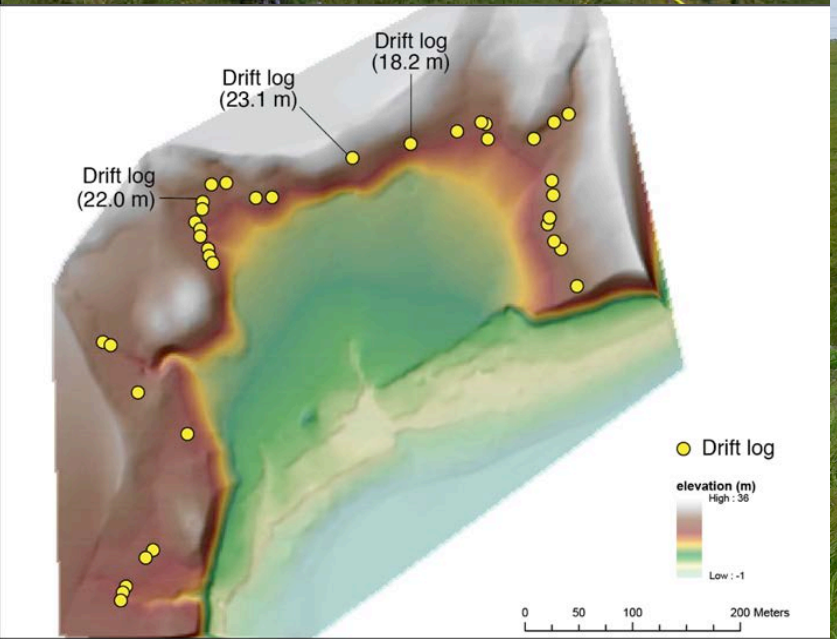


A shallow rupture, such as we illustrate in model D, with about 20m of maximum slip can generate a tsunami that explains both the tsunami runup in Stardust Bay and the tide gauge record at Dutch Harbor

Umnak Island

← North





Umnak Island

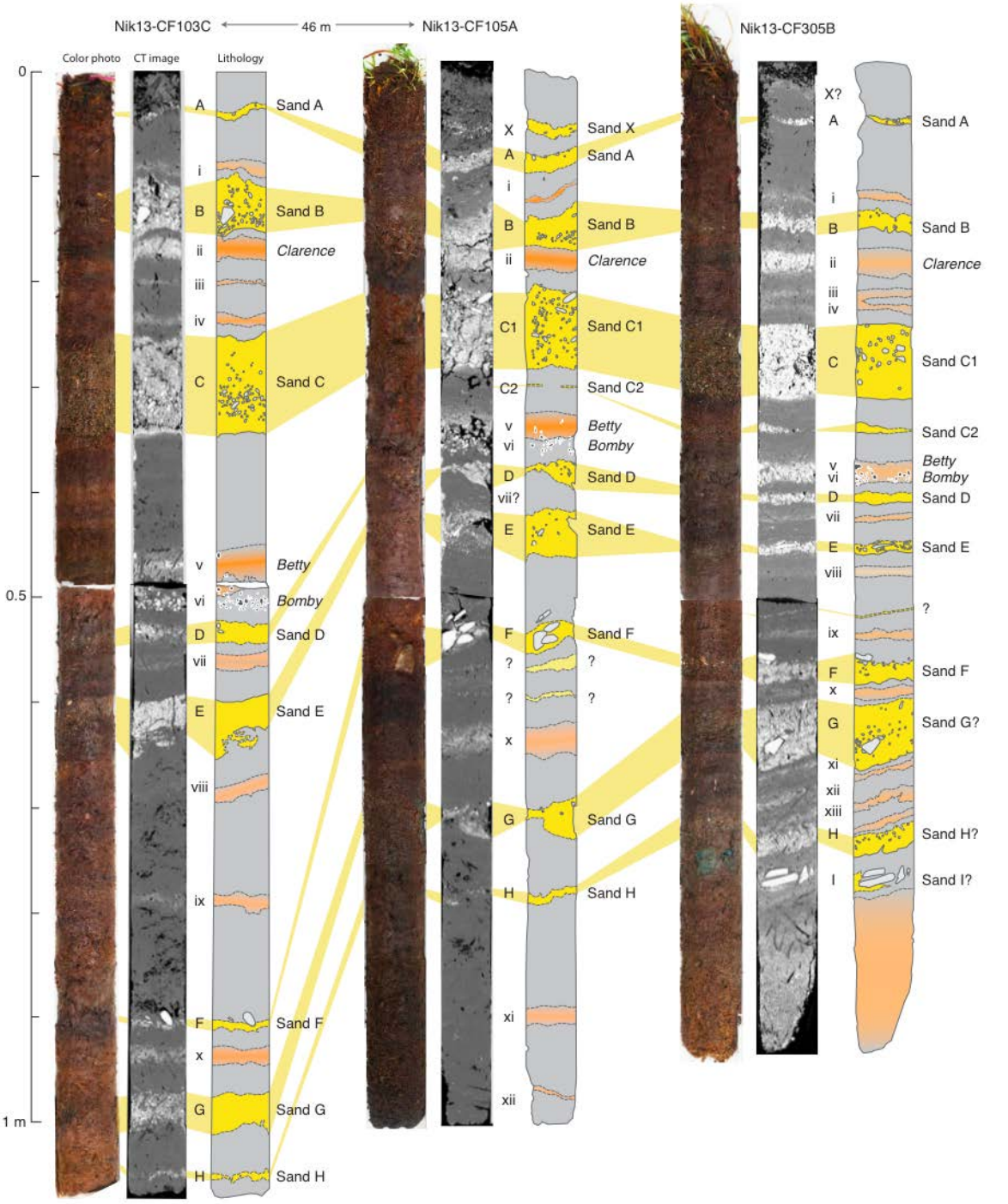
– 9 sand sheets in ~2200 yrs

– Sand sheets meet tsunami criteria

– Youngest sand sheet deposited in 1957

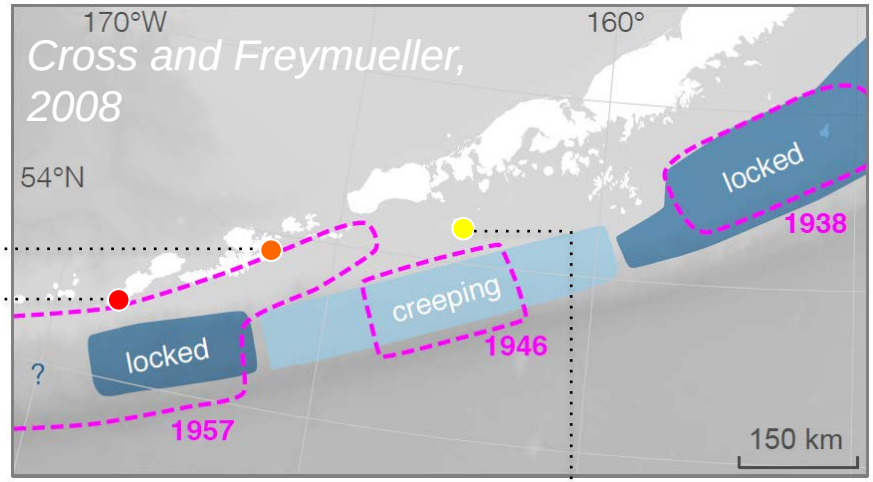
– Stranded drift logs indicate >23 m runup in 1957

– 270–340 yr average tsunami recurrence interval



USGS

How do field observations help define megathrust rupture patches?



Fox Islands

Unusually large tsunamis frequent a part of the Aleutian megathrust.

(Witter et al., 2016
Nicolsky et al., 2016
Witter et al., in 2018)

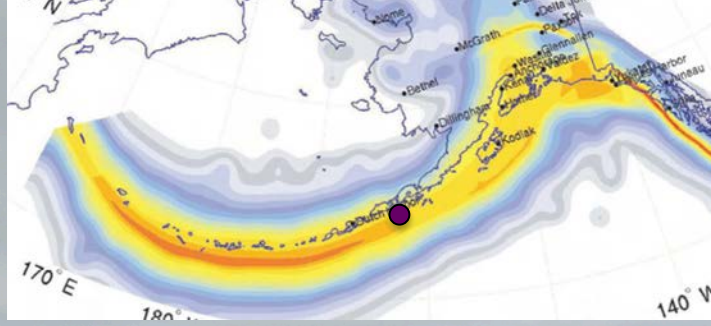
Sanak Island

In addition to the great 1946 tsunami, ancient tsunamis occurred prior to ~2000 yr ago, but not in 1788.

(Engelhart et al., unpublished data)

Sanak Island

Evidence for 1946 tsunami



FINDINGS:

– 5 sand sheets in ~4200 yrs

– Youngest sand sheet deposited in 1946

– Drift logs indicate high runup in 1946

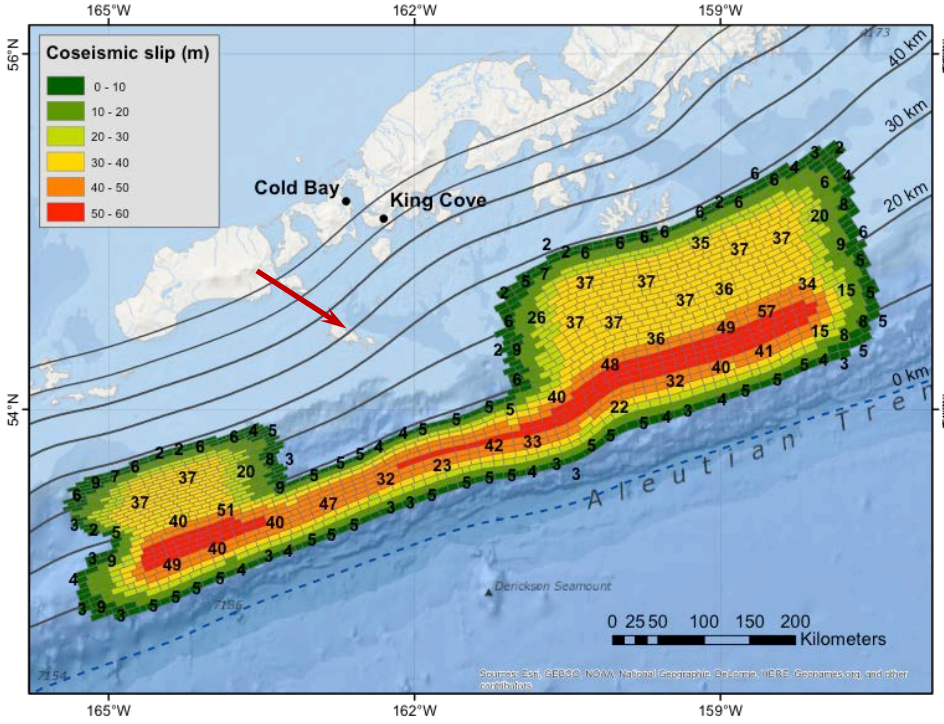
– 4 sand sheets between 2000–4200 yrs ago

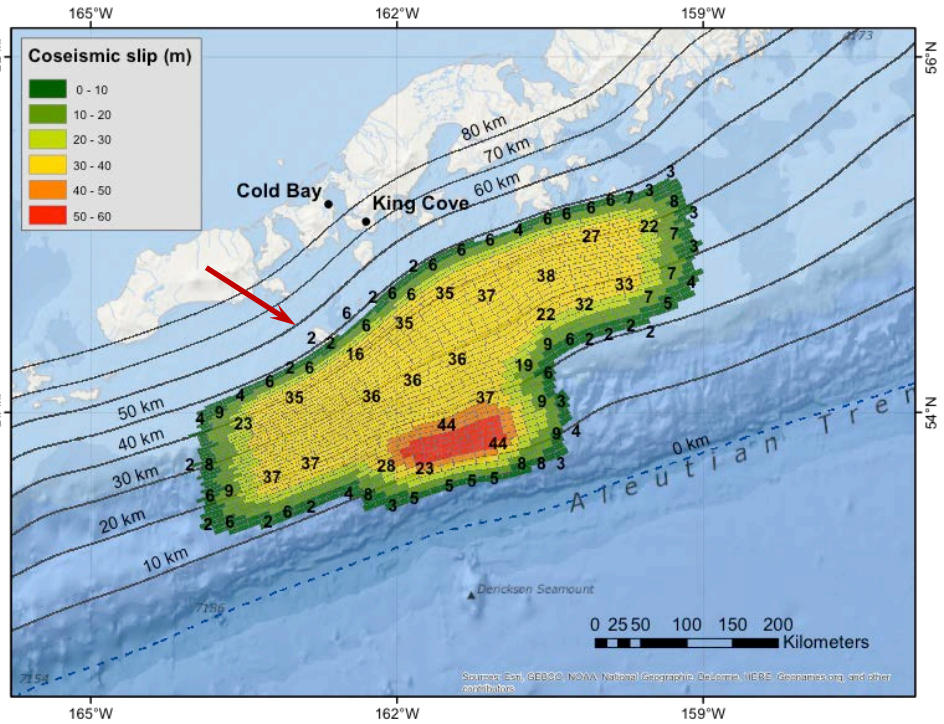
– No evidence for a 1788 tsunami

USGS

Engelhart et al., 2015 GSA

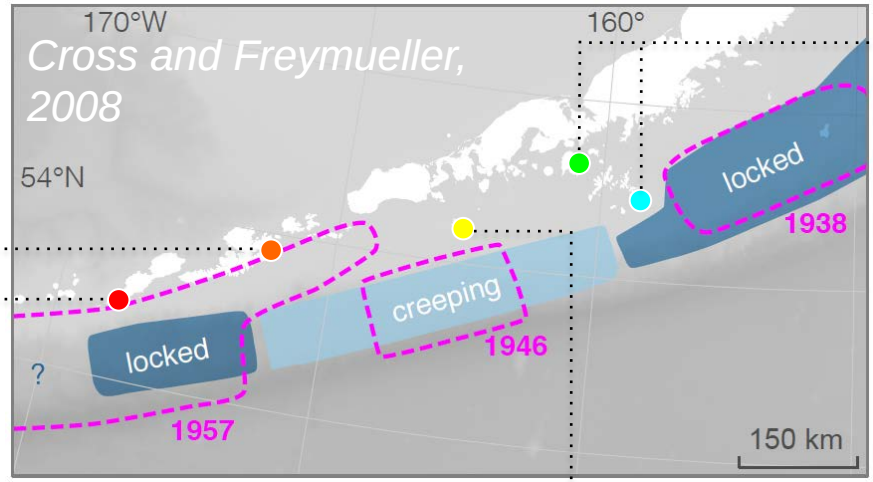
Tsunami sources for Cold Bay and King Cove





At Sanak - in addition to the great 1946 tsunami, ancient tsunamis occurred prior to ~2000 yr ago, but not in 1788.

How do field observations help define megathrust rupture patches?



Shumagin Islands

Absence of evidence for great earthquakes or tsunamis implies that creep has relieved strain for thousands of years.

(Witter et al., 2014)

Fox Islands

Unusually large tsunamis frequent a currently creeping part of the Aleutian megathrust.

(Witter et al., 2015)

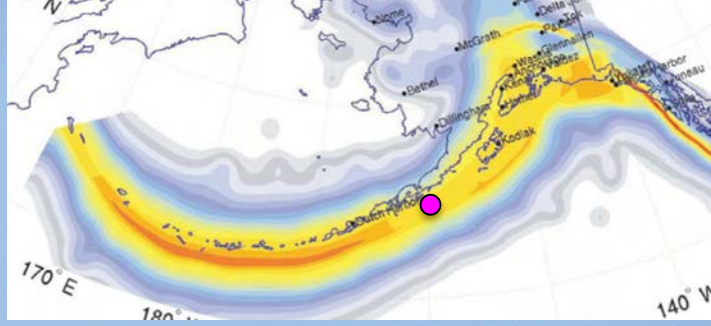
Sanak Island

In addition to the great 1946 tsunami, ancient tsunamis occurred prior to ~2000 yr ago, but not in 1788.

(Engelhart et al., unpublished data)

Simeonof Island

Surprisingly stable



FINDINGS:

– Glaciers retreated after 10.4 ka

– No uplifted shorelines

– No marine deposits above modern tides

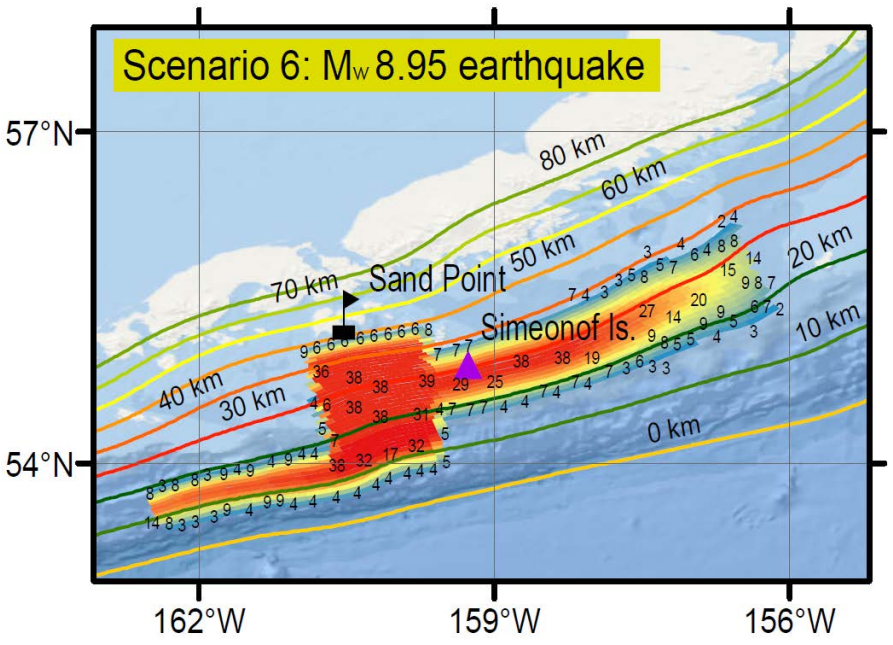
– Storms likely source of low, thin sands

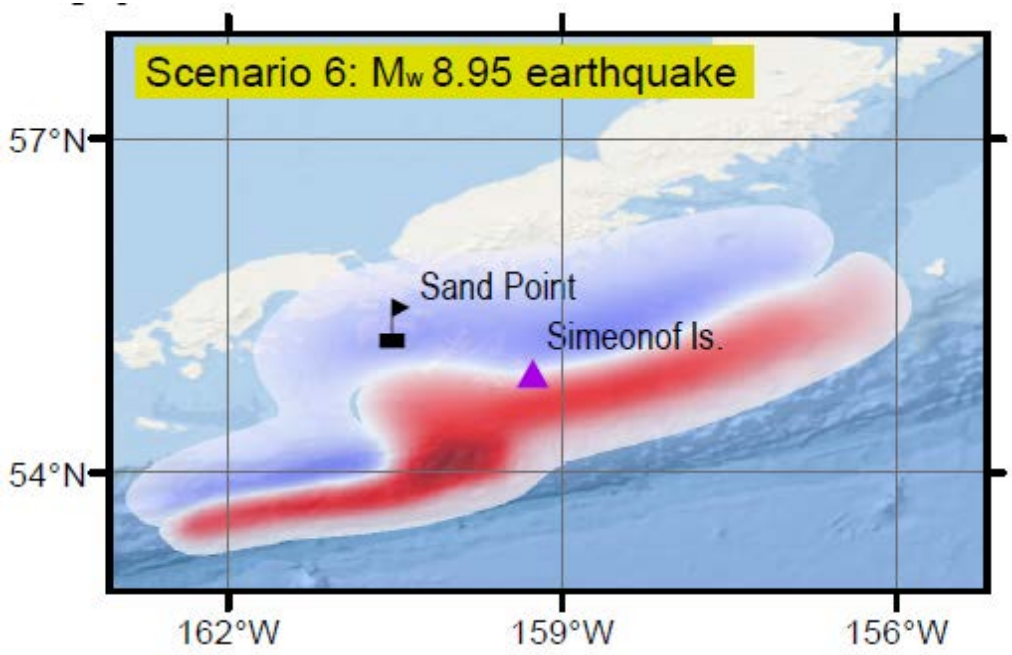
– Earthquake models allow M 7.7–8.5 ruptures near trench

Witter et al., 2014

USGS

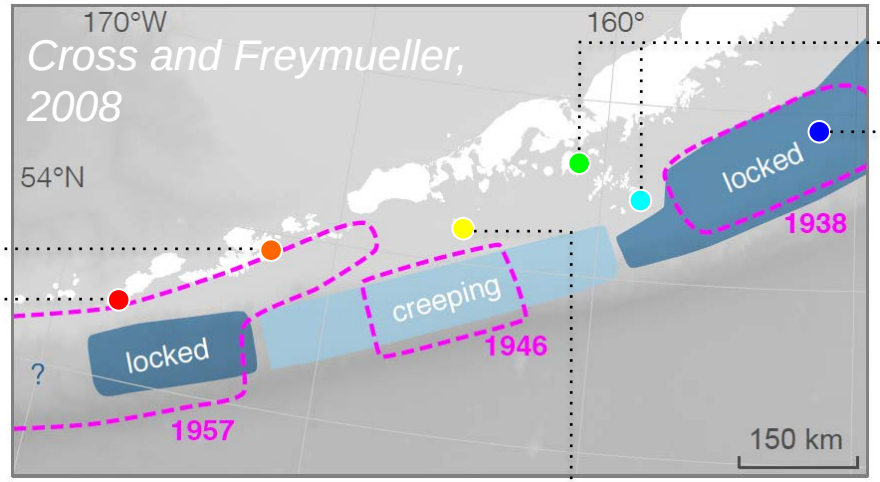
Tsunami sources for Sand Point





Simeonof Island has been surprisingly stable over the past 3500 years.

How often do great megathrust ruptures and tsunamis occur in the Aleutians?



Shumagin Islands

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(Witter et al., 2016)

Sanak Island

In addition to the great 1946 tsunami, ancient tsunamis occurred prior to ~2000 yr ago, but not in 1788.

(Engelhart et al., unpublished data)

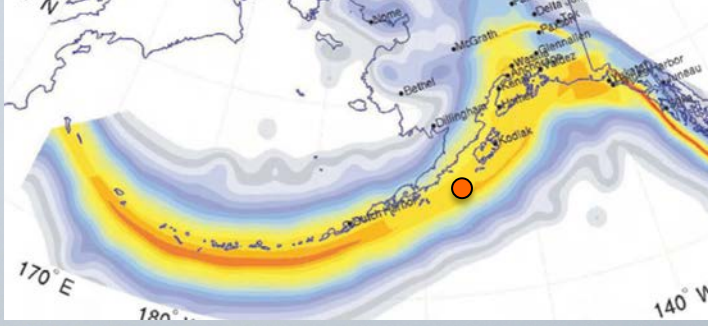
Chirikof Island

Ruptures of the megathrust probably launched large tsunamis every 180–270 yrs over the past 3500 yrs, including in 1788.

(Nelson et al., 2015)

Chirikof Island

Dropping like a stone



FINDINGS:

– Multiple sand sheets in past 3,500 yrs

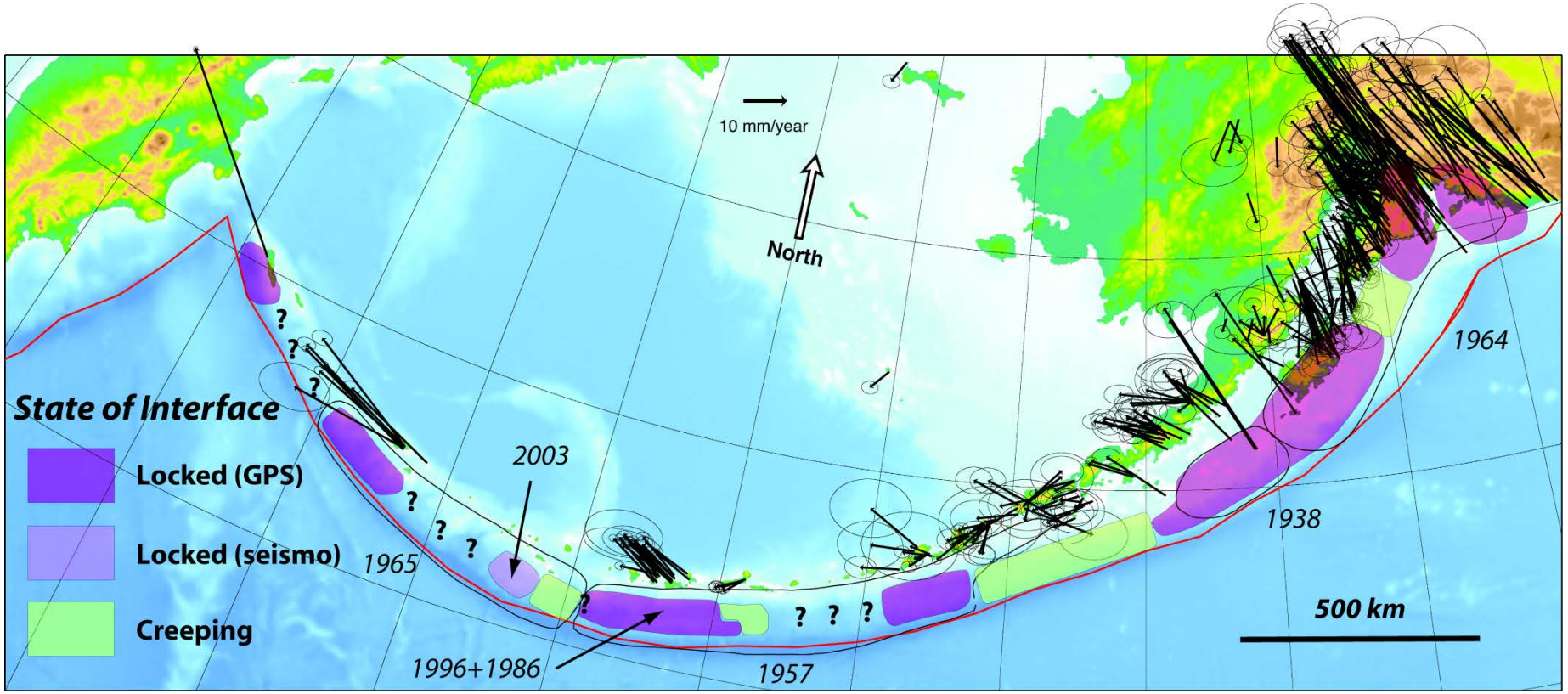
– Sand sheets deposited by tsunamis in 1788 and 1938

– 180–270 yr average tsunami recurrence

Nelson et al., 2015

USGS

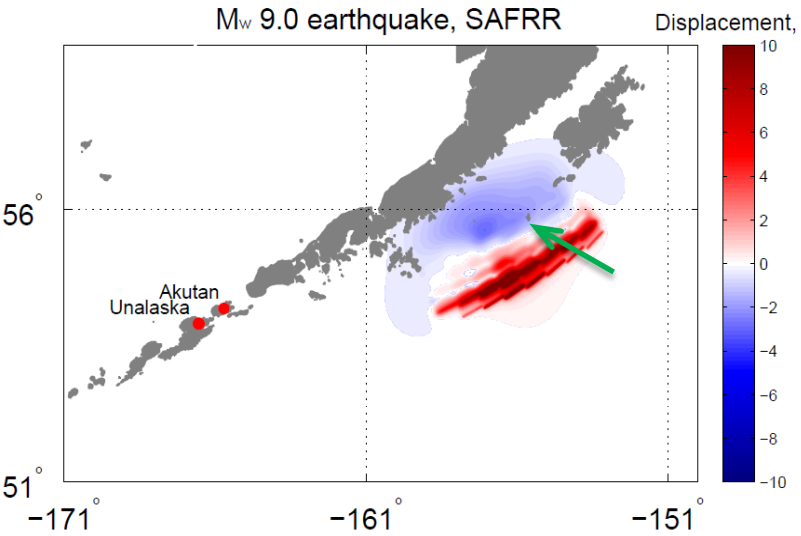
What could GPS observations tell us?

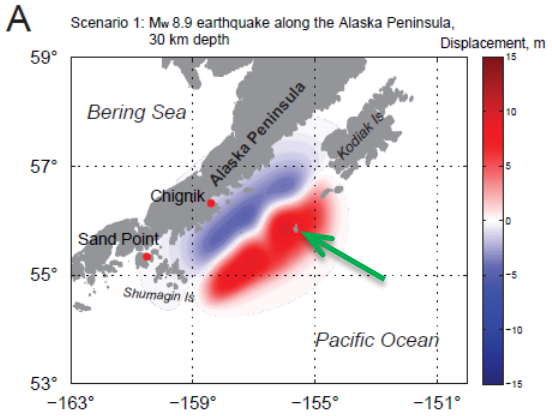


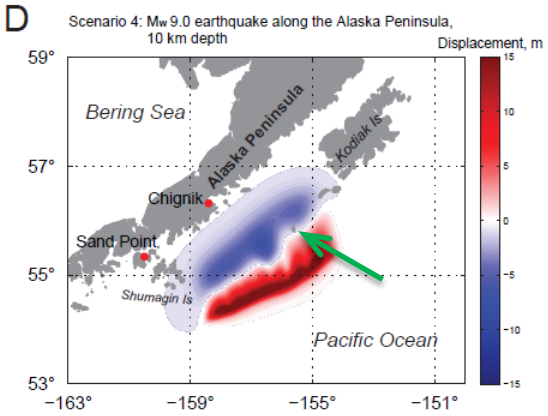
Freymueller et al. (2008)

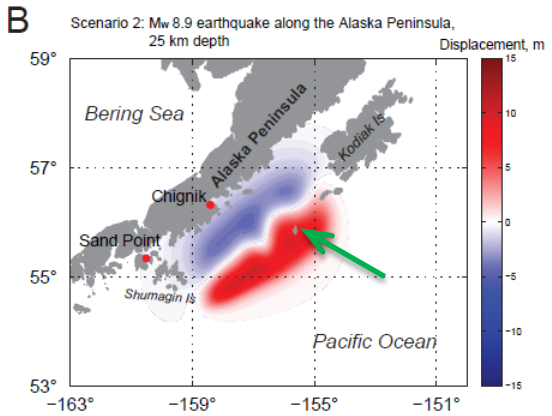
Sources near Chirikof Island

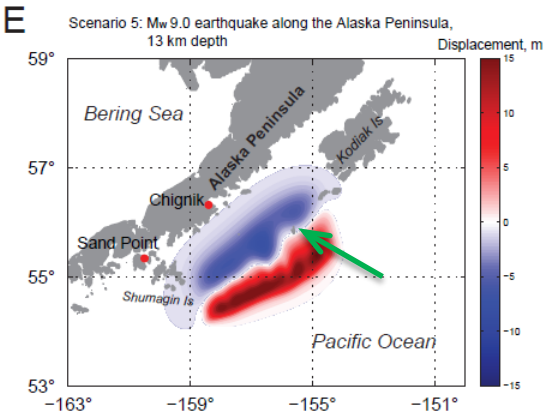
currently, it is subsiding

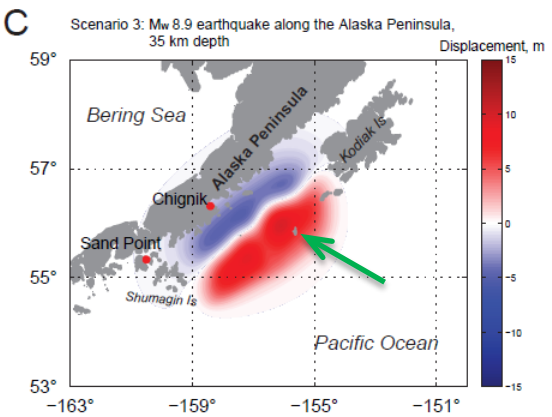


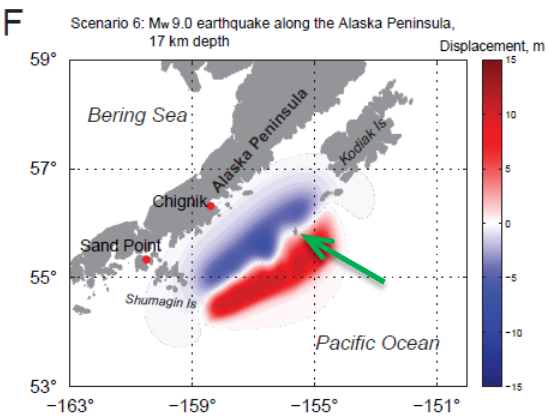






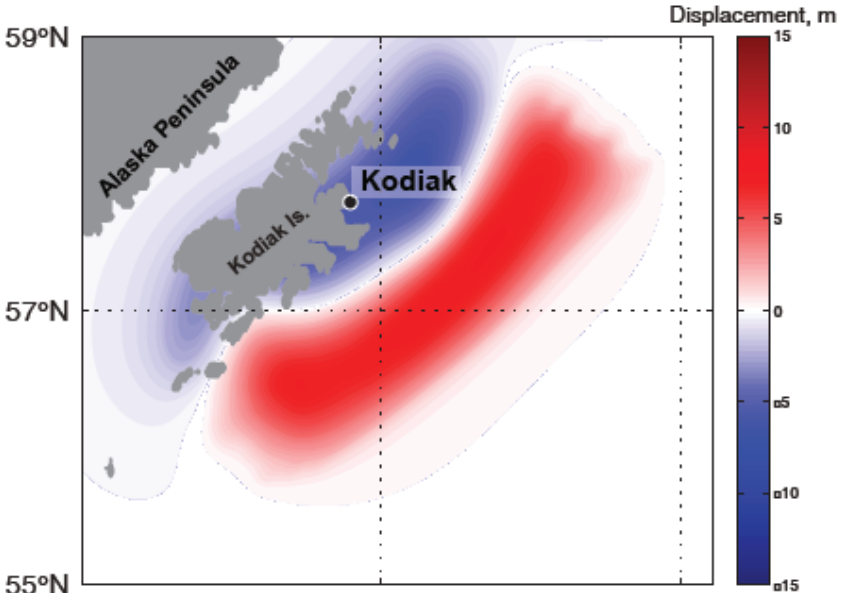




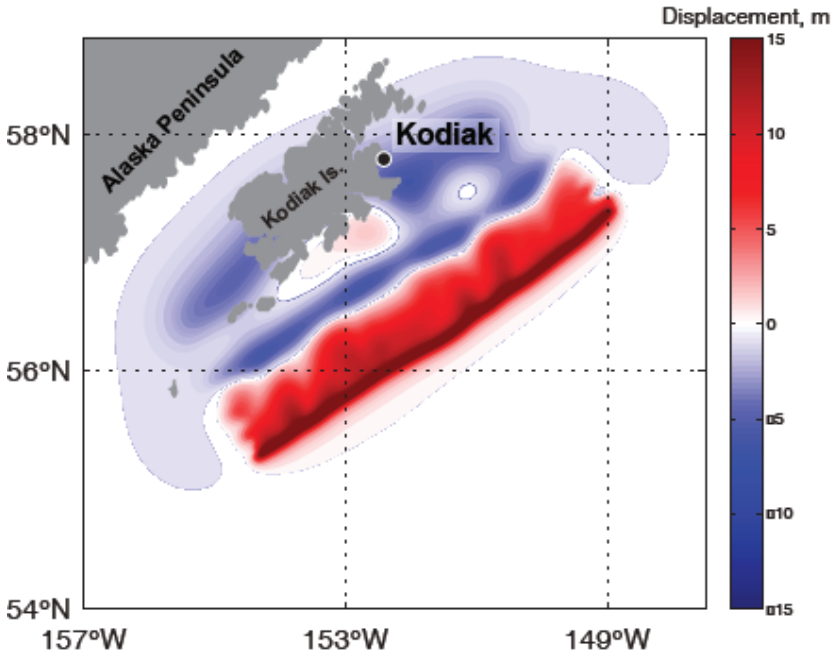


Developing tsunami sources for Kodiak

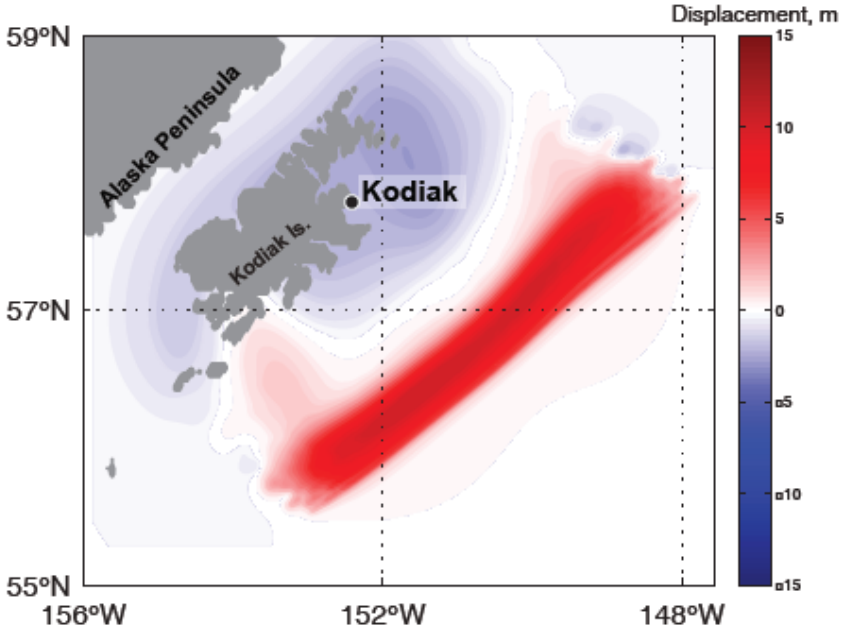
Scenario 4: Mw 9.0 earthquake in the area of Kodiak Island, 20 km depth.



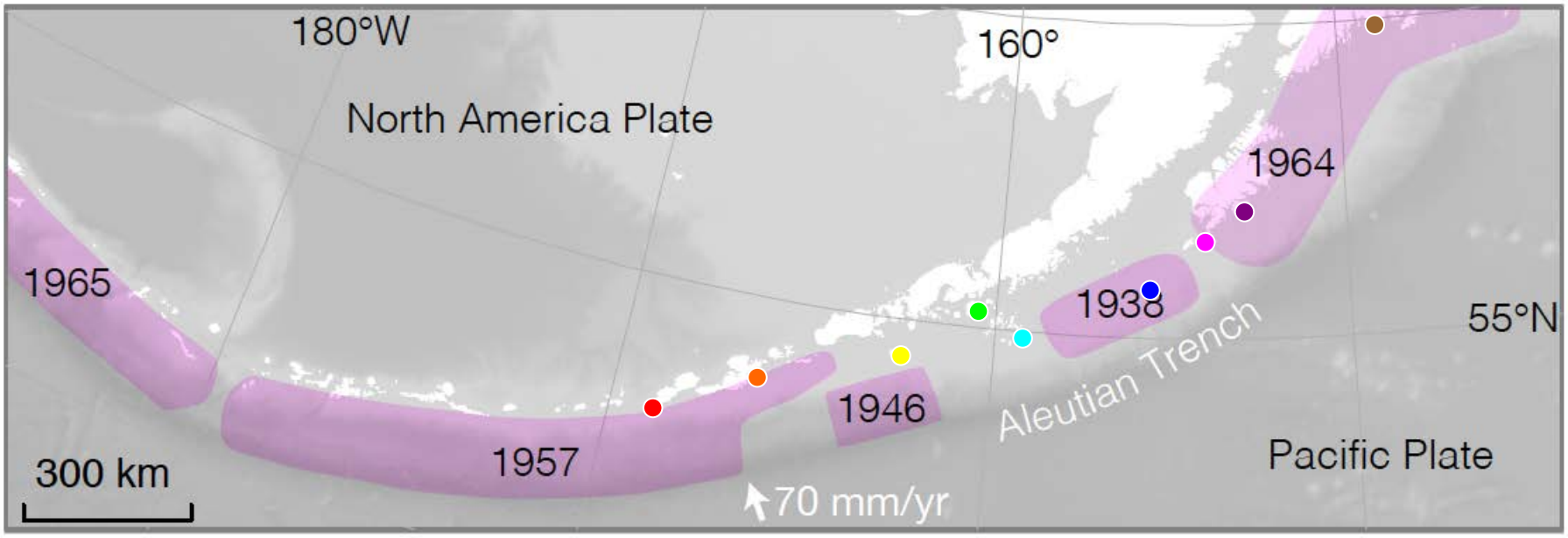
Scenario 9: Mw 9.25 earthquake in the area of Kodiak Island with 50 m of maximum slip.



Scenario 2: Mw 9.1 earthquake in the area of Kodiak Island, 10 km depth.



Frontiers in Alaska



Insights from the field:

- *Field evidence implies varied rupture behavior without fixed segment boundaries*
- *Currently creeping parts of the megathrust may have ruptured in the past (or not!).*
- *Evidence for a 1788 megaquake does not exist.*

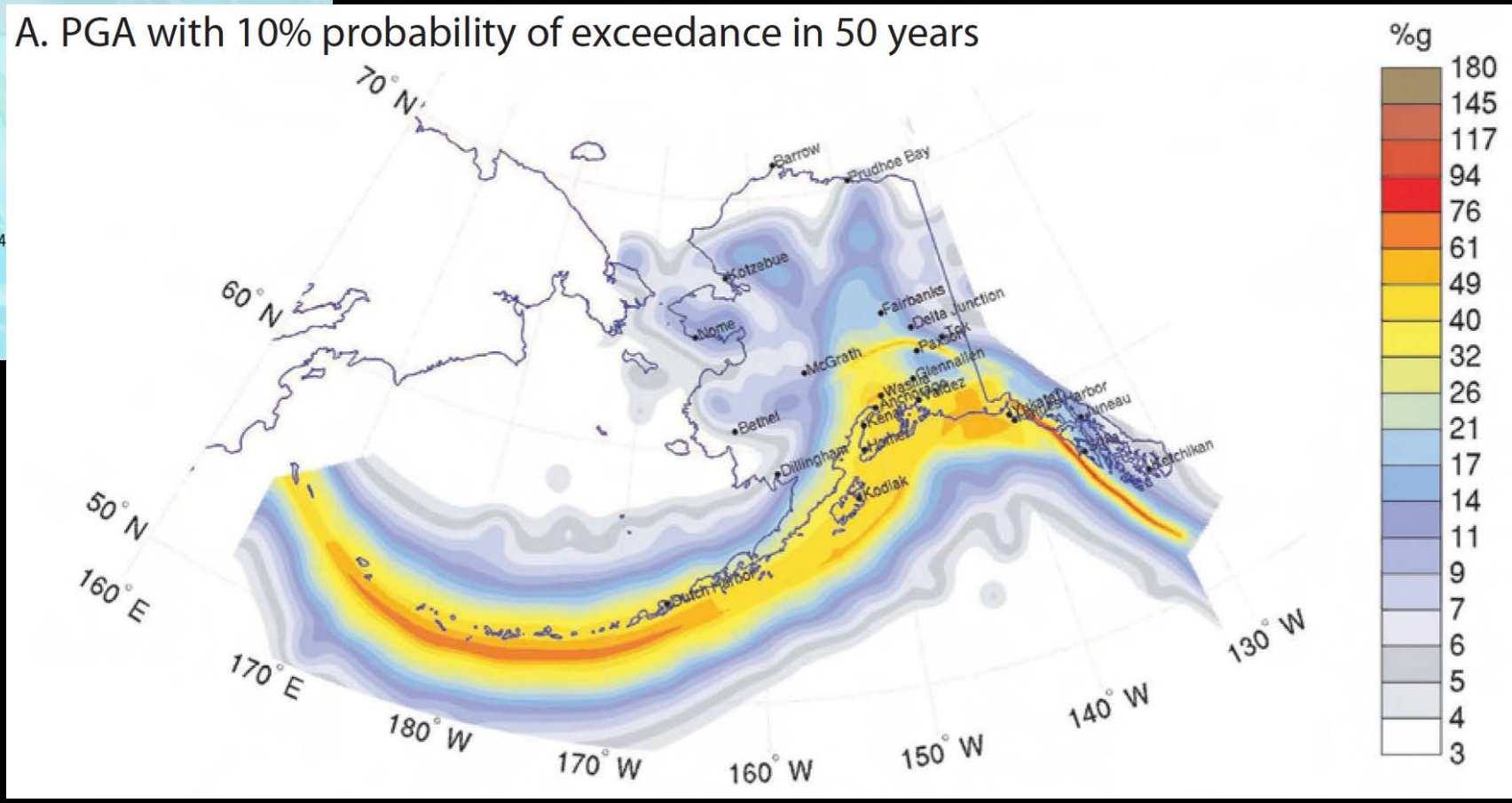
USGS
science for a changing world

Revision of Time-Independent Probabilistic Seismic Hazard Maps for Alaska

Open-File Report 2007–104

U.S. Department of the Interior
U.S. Geological Survey

2007 USGS Seismic Hazard Map:
Alaska-Aleutian Subduction Zone

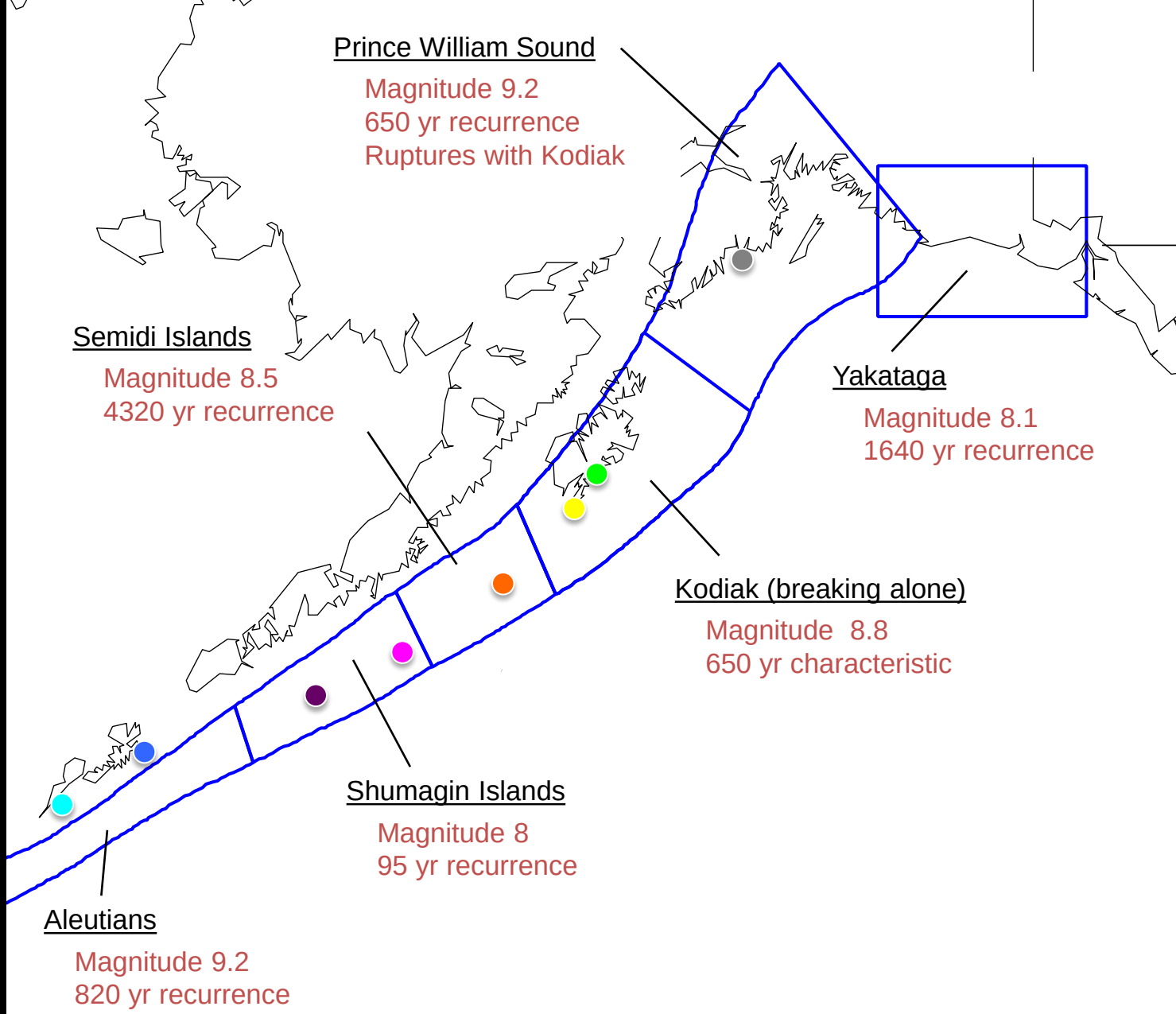


Wesson, Boyd, Mueller, Bufe, Frankel, and Petersen, 2007

USGS

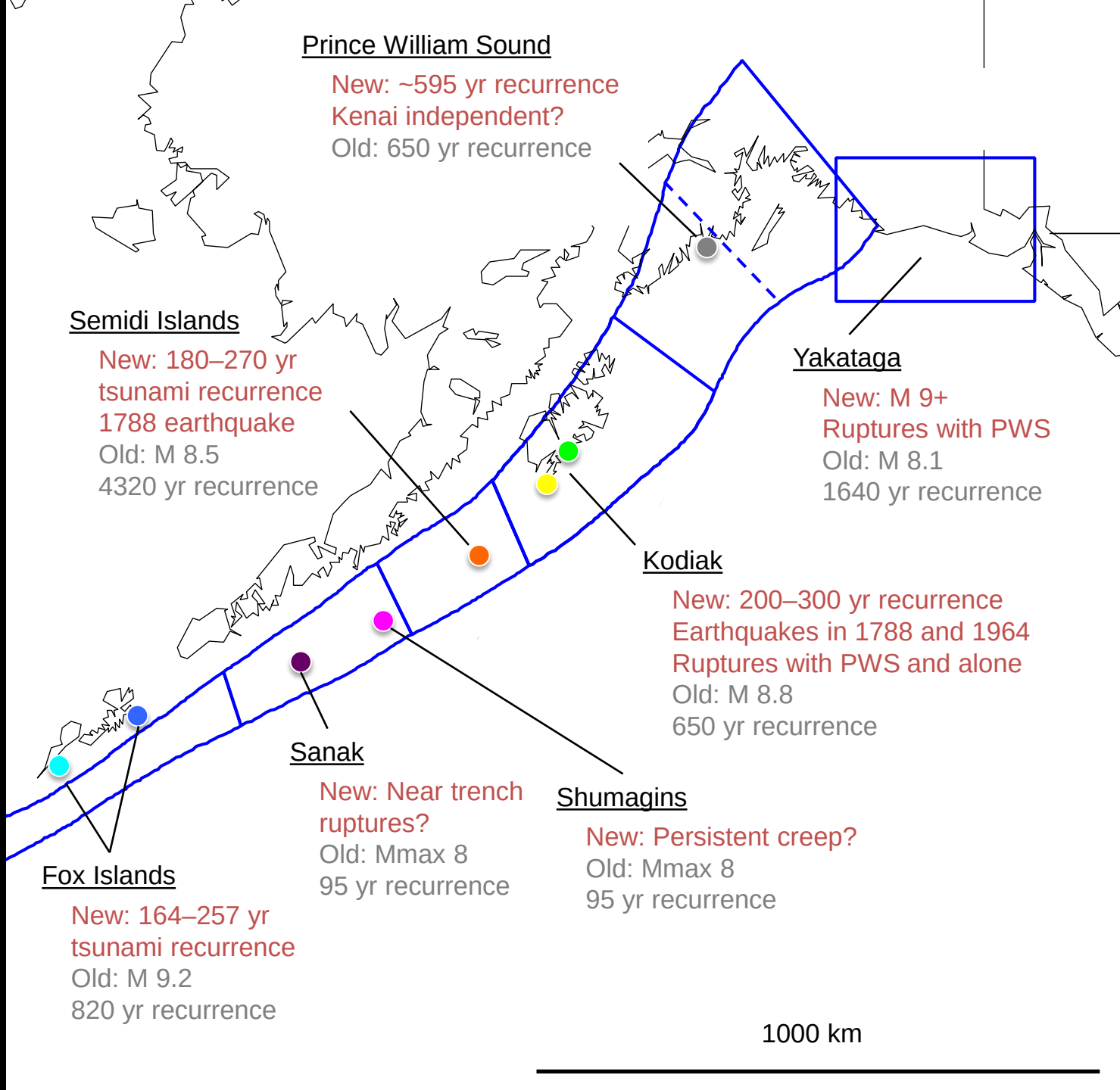
2007 Hazard Maps:

Defined by earthquake magnitude & recurrence



Wesson, Boyd, Mueller, Bufe, Frankel, and Petersen, 2007

New findings will guide revisions



USGS

Summary of paleoseismology in the 1964 rupture zone

Hutchinson and Crowell, 2007

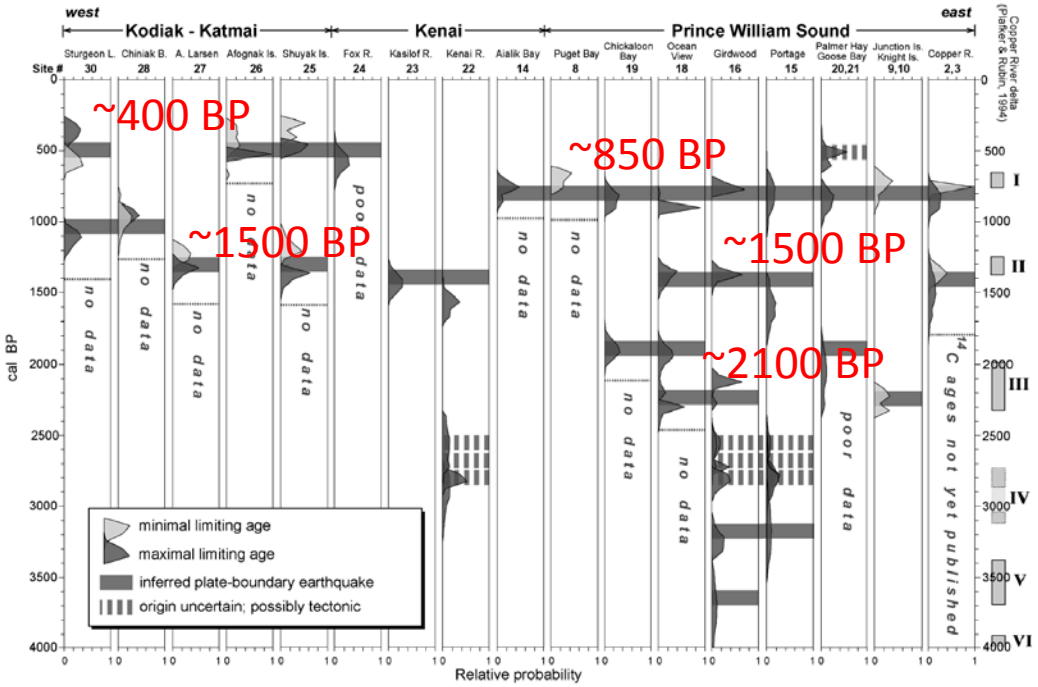


Figure 3 Ages of plate-boundary earthquakes at the Alaska subduction zone inferred from geological evidence of episodes of abrupt sea-level change. Site locations are shown in Figure 2. The thin dotted and hatched lines mark the maximum time-depth of evidence in each region. Periods beyond these limits are marked "no data."

Shennan et al. 2016

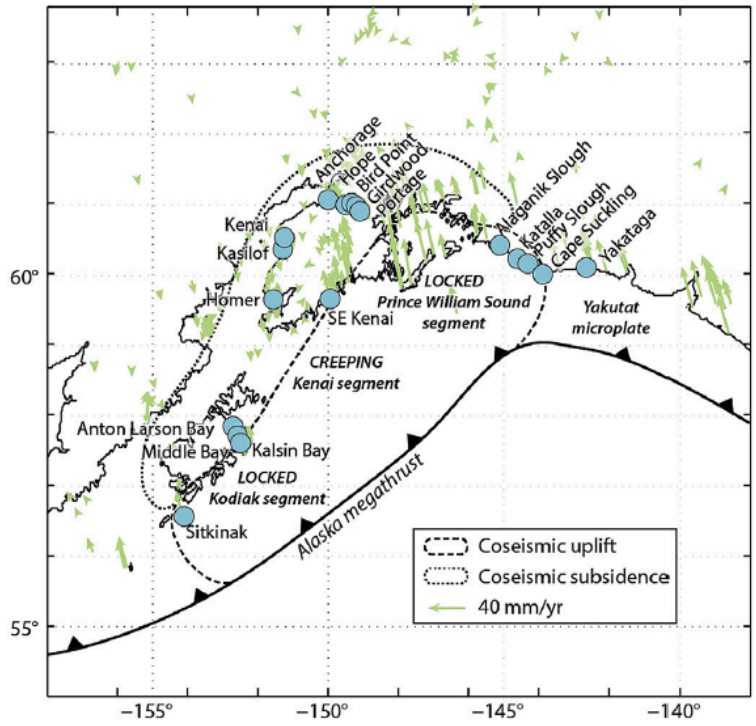


Fig. 3. Zones of coseismic uplift and subsidence in 1964 (after Plafker, 1969), present-day velocities (http://www.gps.alaska.edu/jeff/Chapman_GPS_velocities.html accessed 13 July 2015) and location of coastal marsh sites providing paleoseismic records (circles).

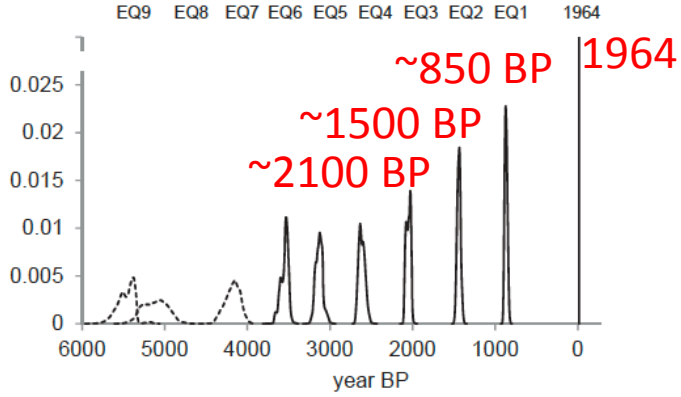
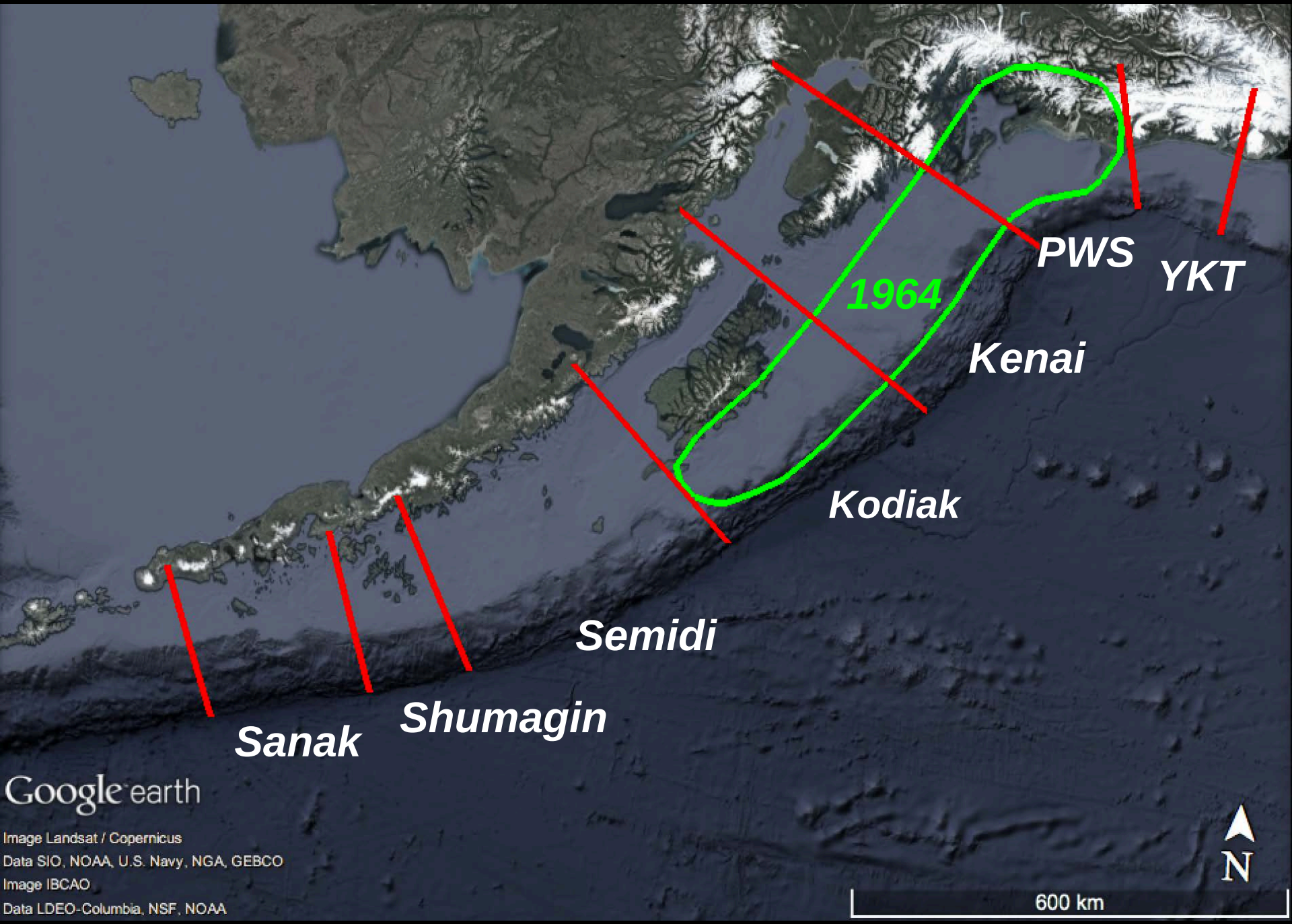
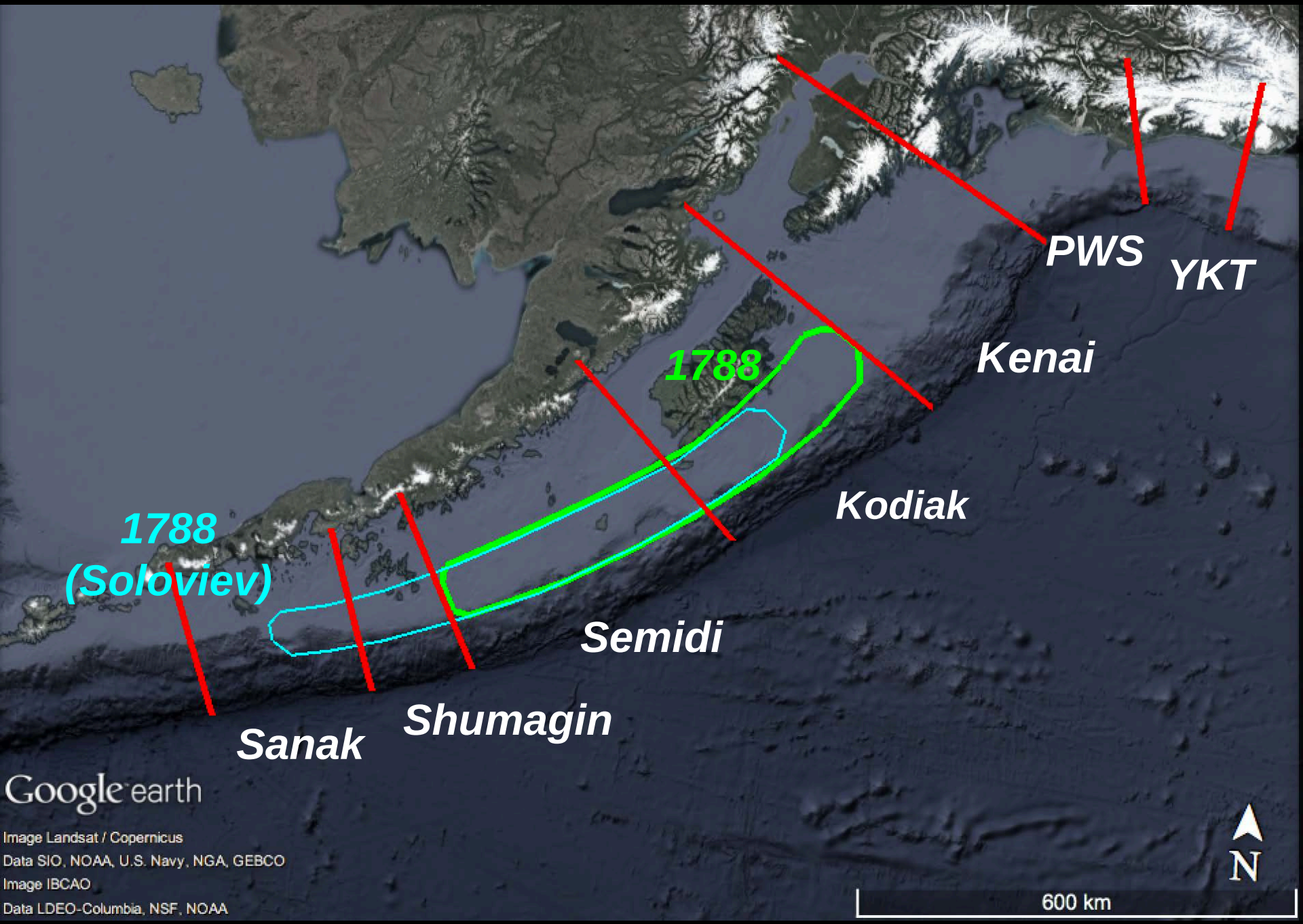
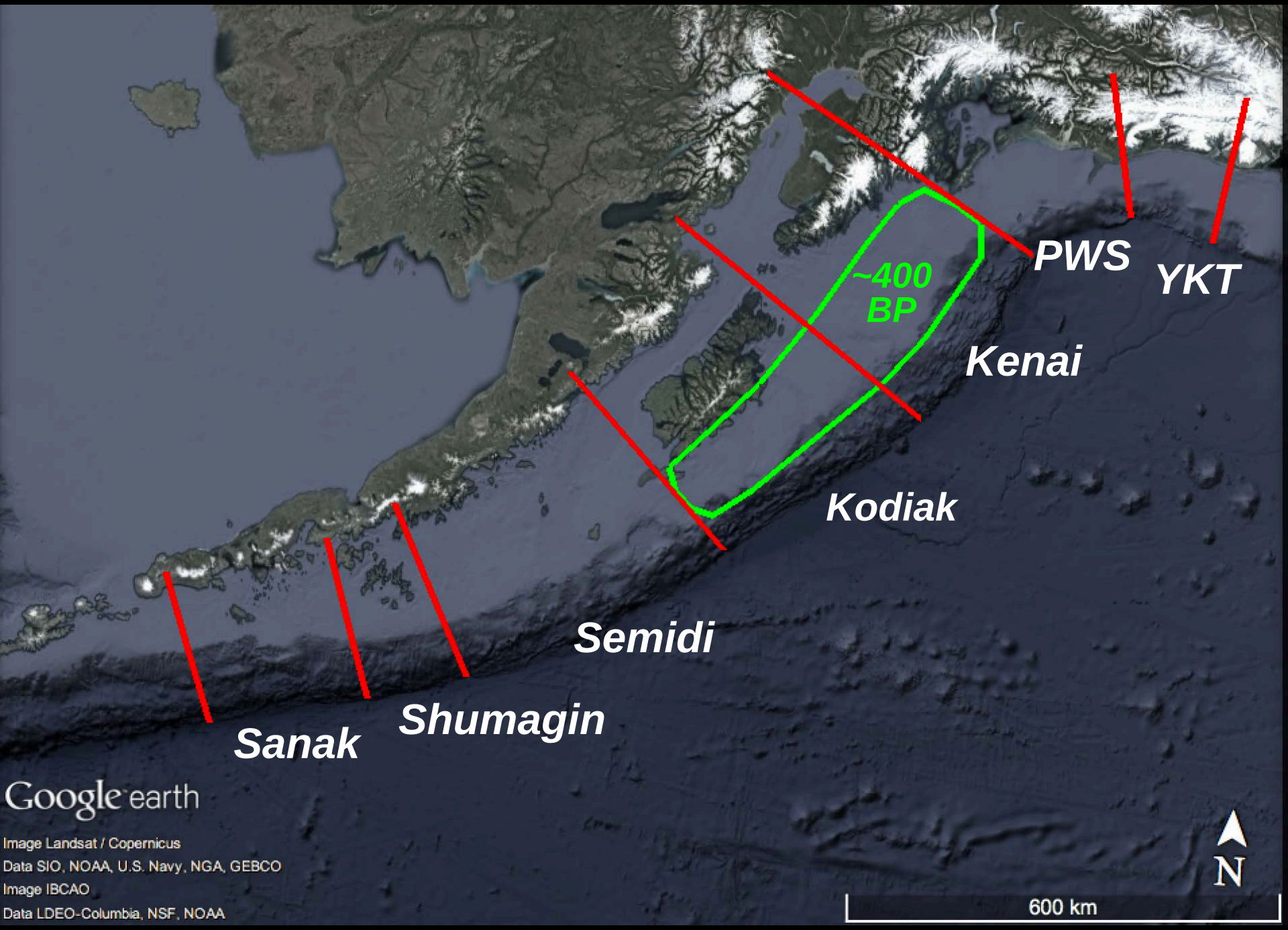
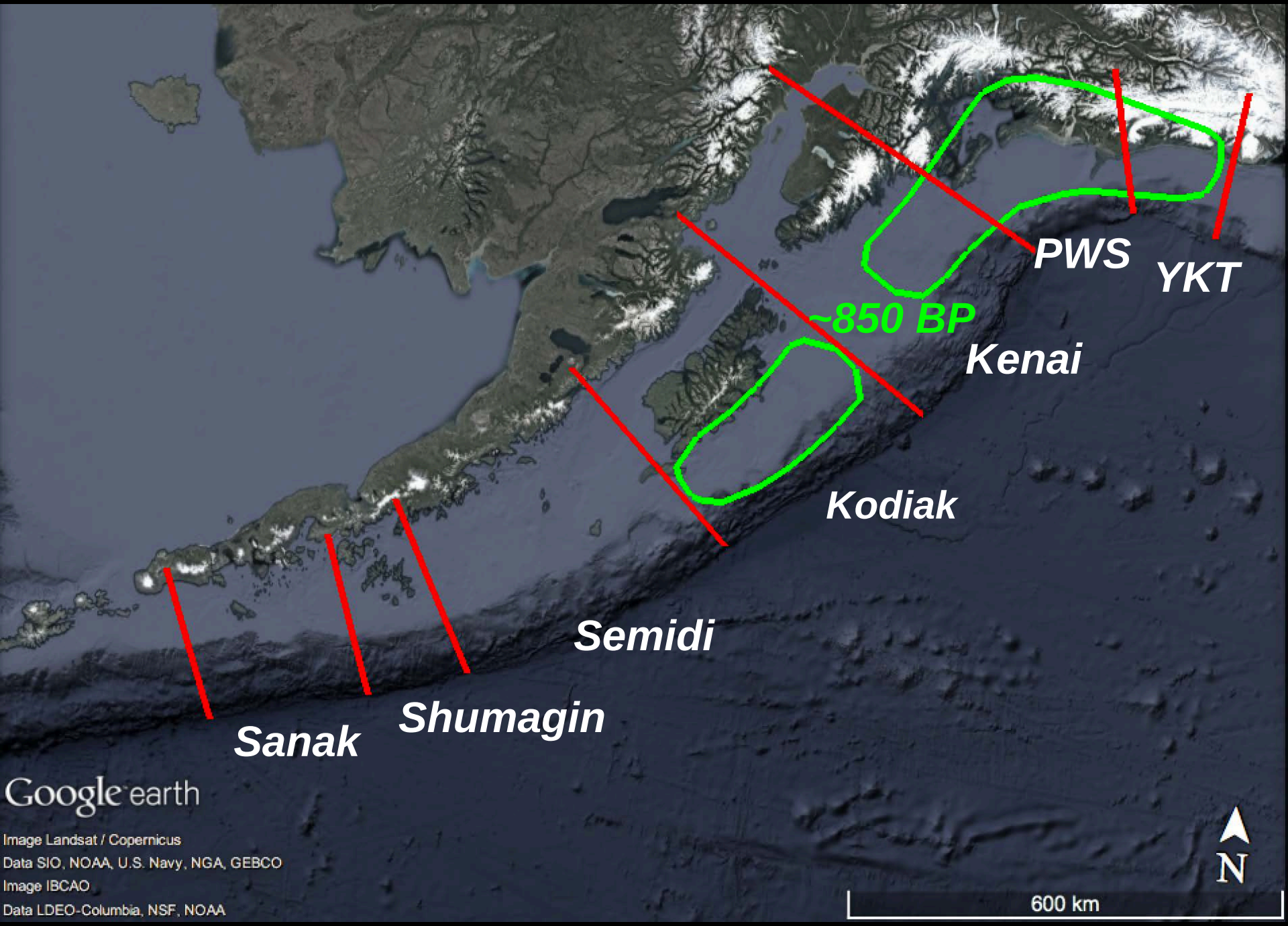


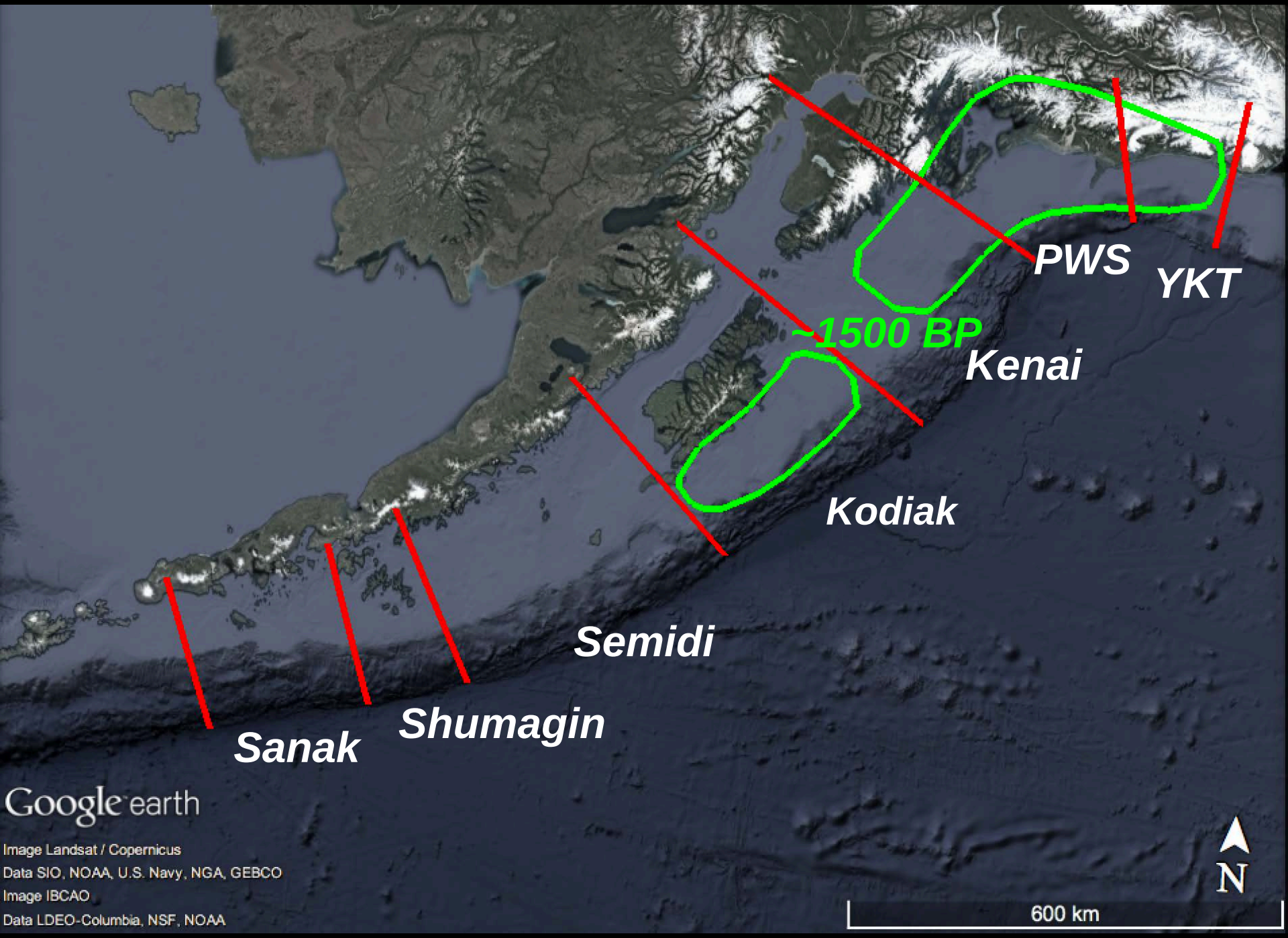
Fig. 4. Probability density functions for earthquake ages from sites in the Prince William Sound segment (data from Shennan et al., 2014b, 2014c).

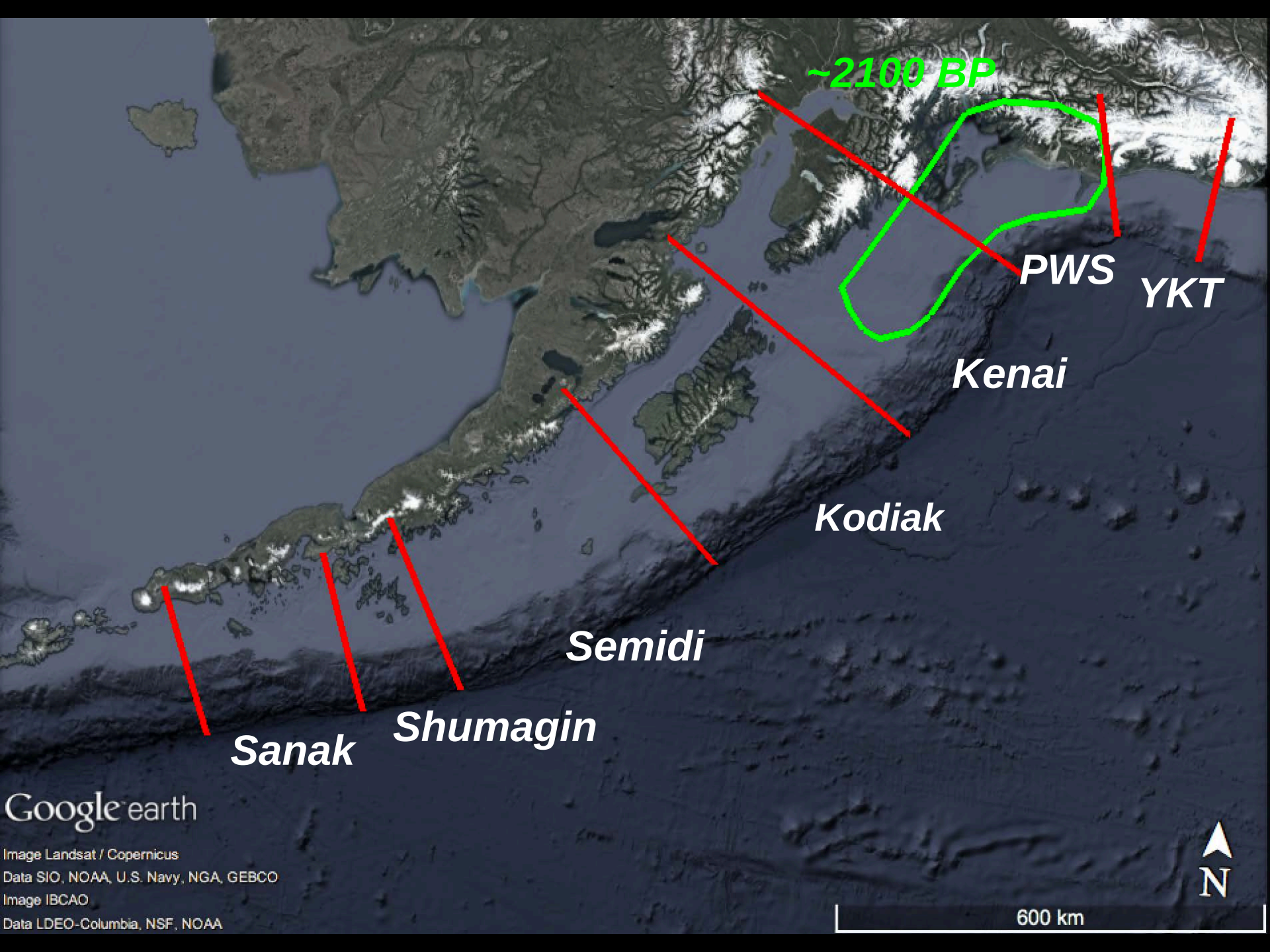

PWS
YKT
1964
Kenai
Kodiak
Semidi
Shumagin
Sanak
Google earth
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Data LDEO-Columbia, NSF, NOAA
N
600 km


PWS
YKT
1788
Kenai
Kodiak
1788
(Soloviev)
Semidi
Shumagin
Sanak
Google earth
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Data LDEO-Columbia, NSF, NOAA
N
600 km


PWS
YKT
~400
BP
Kenai
Kodiak
Semidi
Shumagin
Sanak
Google earth
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Data LDEO-Columbia, NSF, NOAA
N
600 km

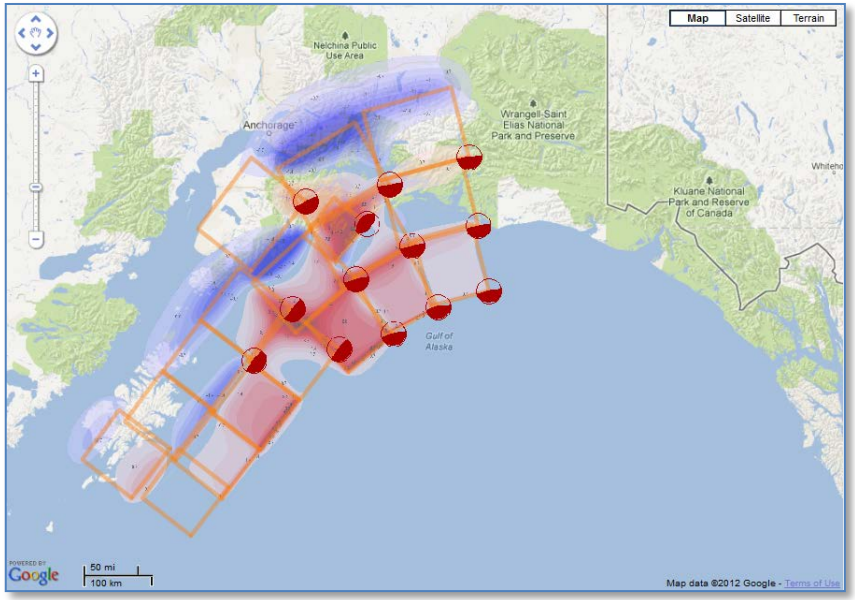

PWS
YKT
~850 BP
Kenai
Kodiak
Semidi
Shumagin
Sanak
Google earth
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Data LDEO-Columbia, NSF, NOAA
N
600 km


PWS
YKT
~1500 BP
Kenai
Kodiak
Semidi
Shumagin
Sanak
Google earth
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Data LDEO-Columbia, NSF, NOAA
N
600 km


~2100 BP
PWS
YKT
Kenai
Kodiak
Semidi
Shumagin
Sanak
Google earth
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Data LDEO-Columbia, NSF, NOAA
N
600 km

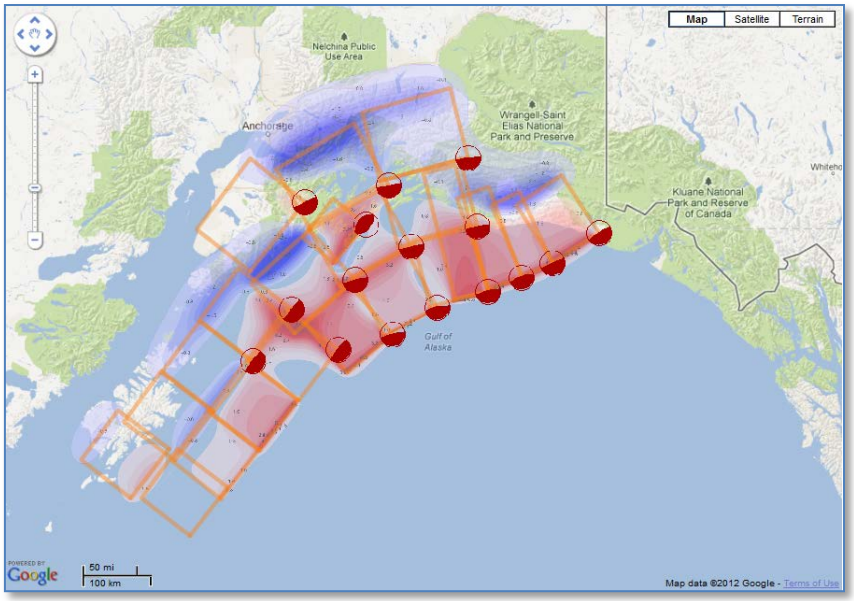
Applications to the Gulf of Alaska sources

Model based on the 1964 earthquake



Johnson and others (1996)

Model incorporating paleoseismic data



Multi-Segment Great Alaska Earthquake (Suleimani et al.)

Conclusions

- Active paleoseismic research brings new data to define credible tsunami sources
- Data is incorporated into multiple activities (e.g. Powell Center workgroup, Seismic Hazard Map updates)
- Information is actively used by states to develop potential tsunami sources