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Lithospheric structure in and around slow slip in the Alaska subduction region

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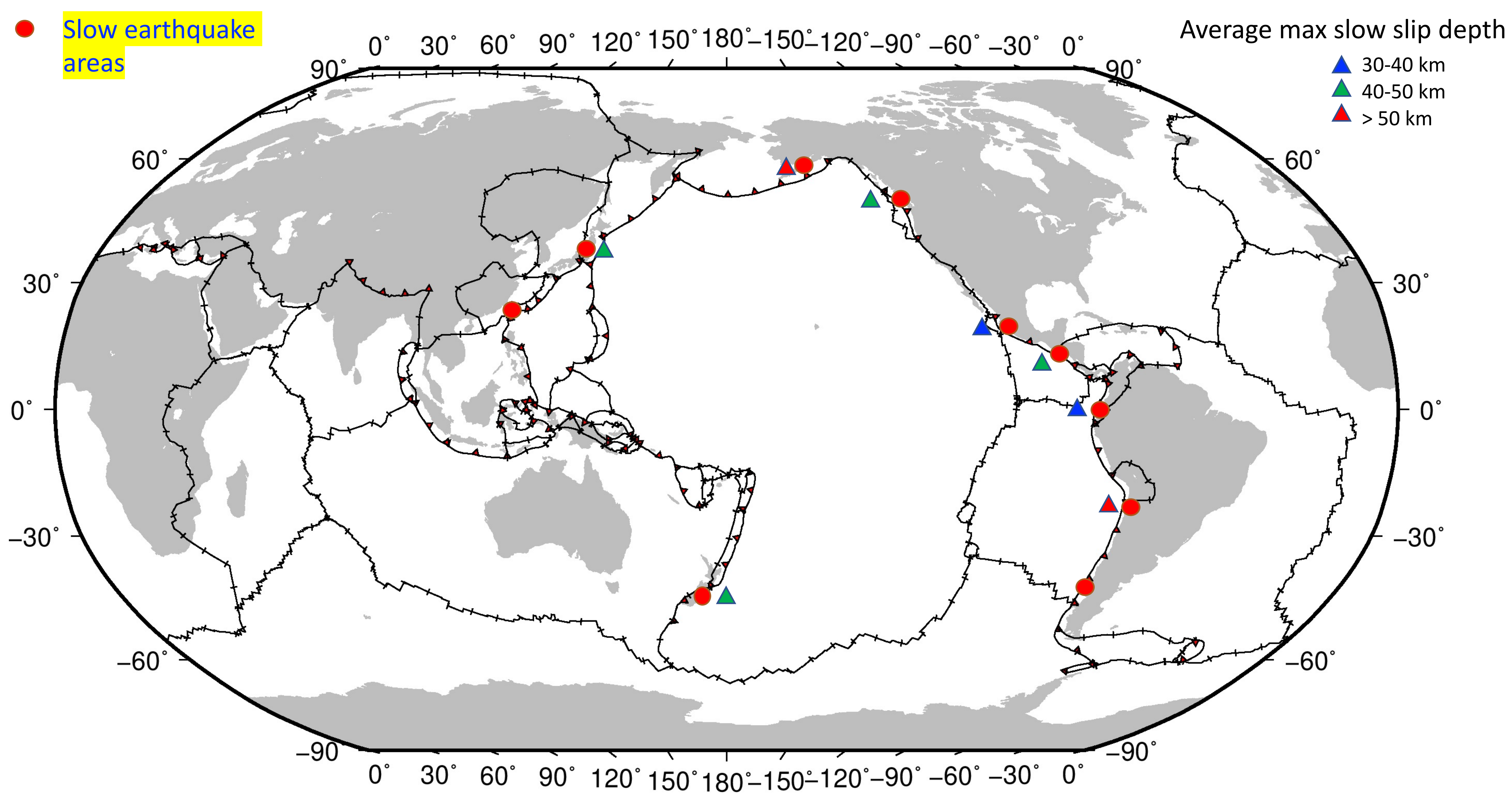
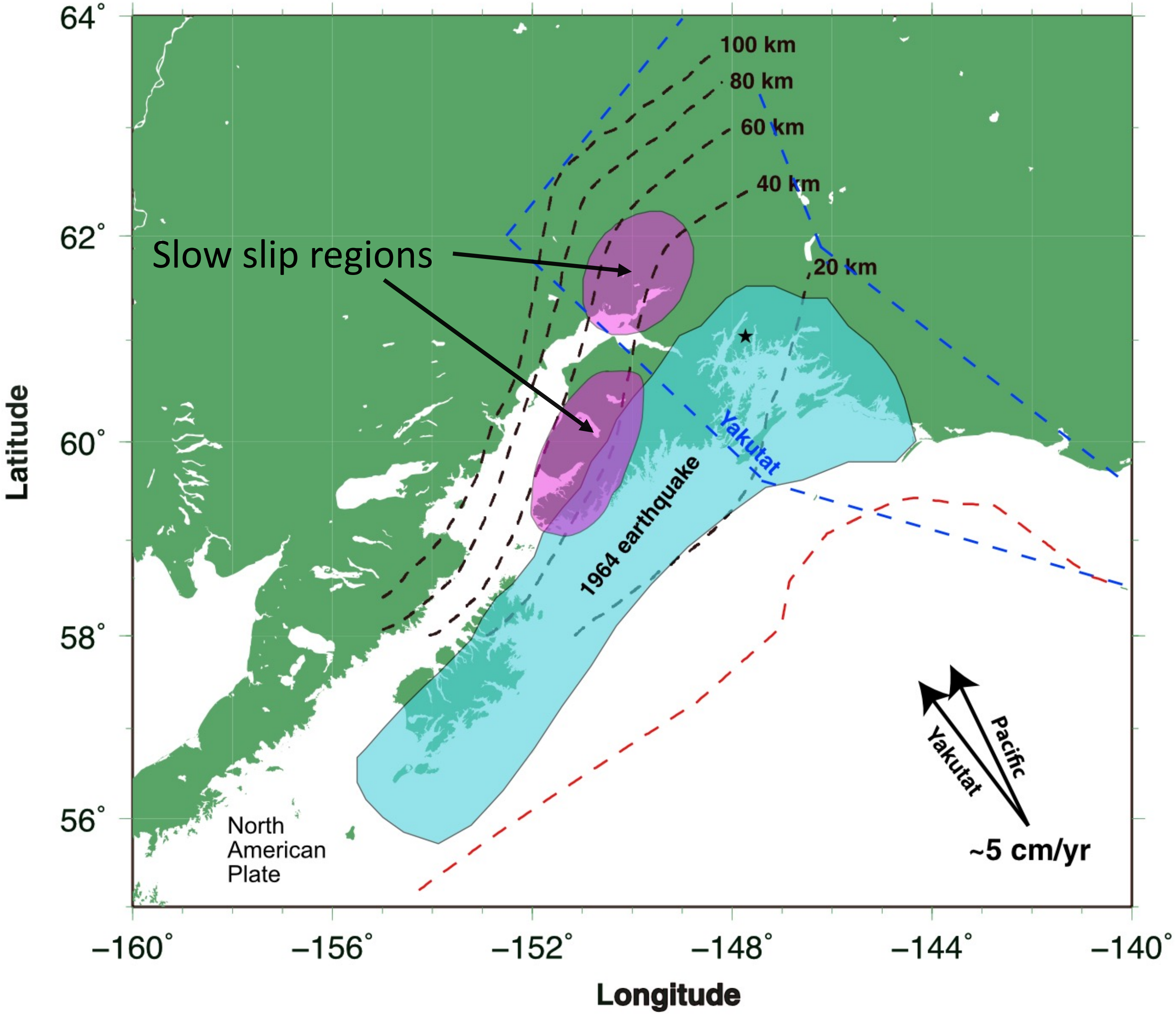


Deep slow slip is mainly found in the Chile and Alaska regions

Tectonics and Objectives



Fu et al. 2015; Li et al. 2016; Wei et al. 2012- slow slip

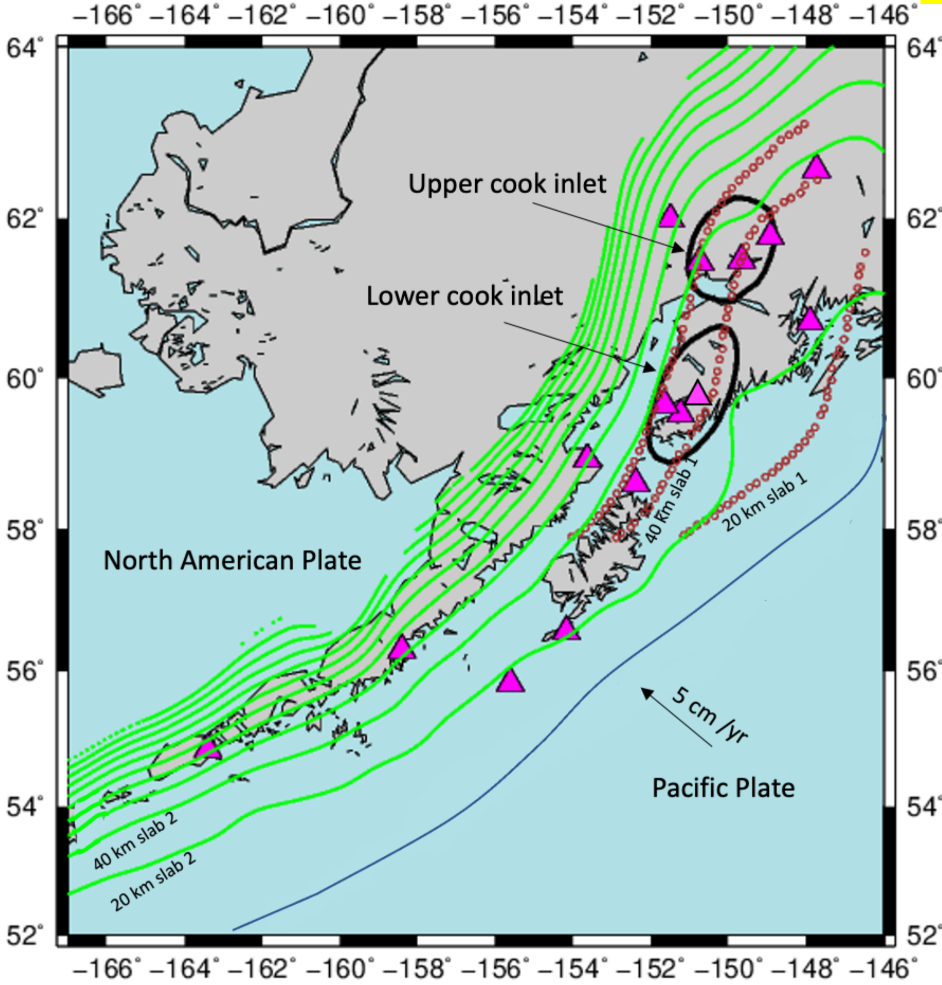
Slow slip areas:
Upper cook Inlet (UCI)
Lower cook Inlet (LCI)

Yakutat terrane undergoes subduction with North American plate.

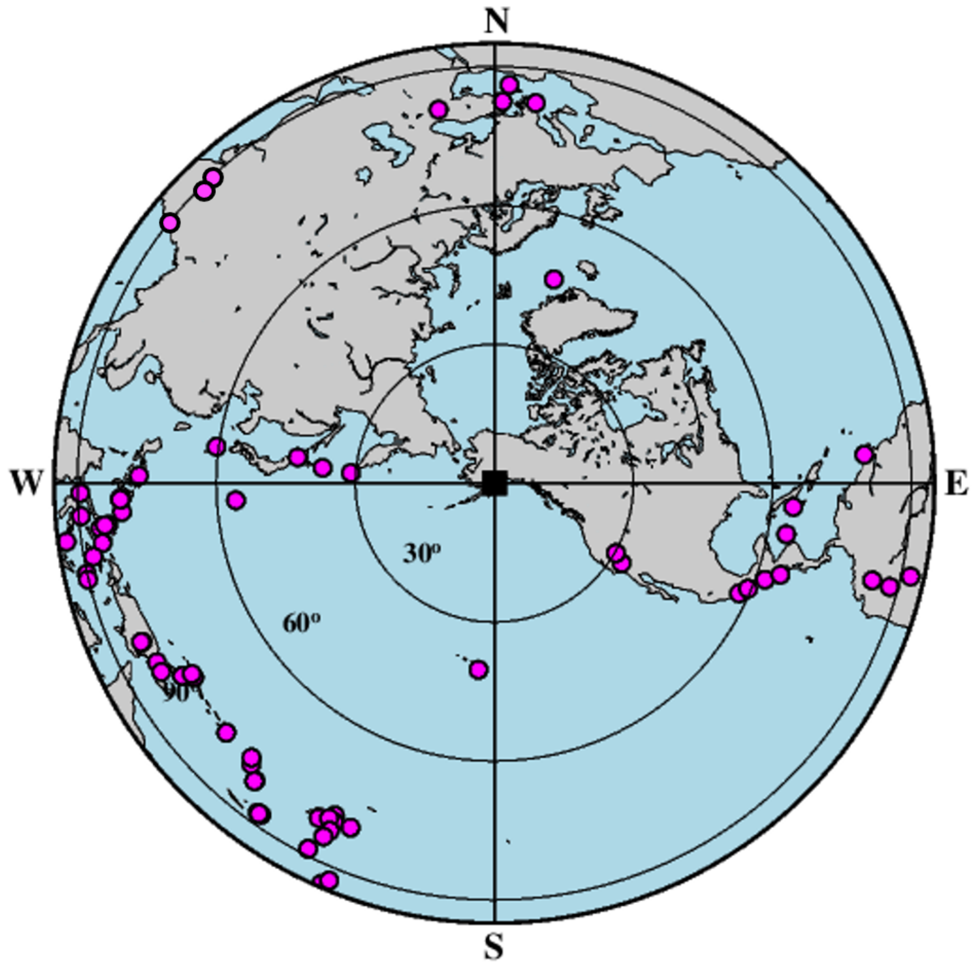
Objective:

In this study we characterize the property of the upper lithosphere in the Alaska subduction region in and around the slow slip region and further away from the slip region along the subduction forearc

Station Map and Earthquake distribution



Stations distributed along the forearc inside, close and away from the slip regions



Teleseismic events more than magnitude 6
Less than 30º – triplication
More than 95º – core phases

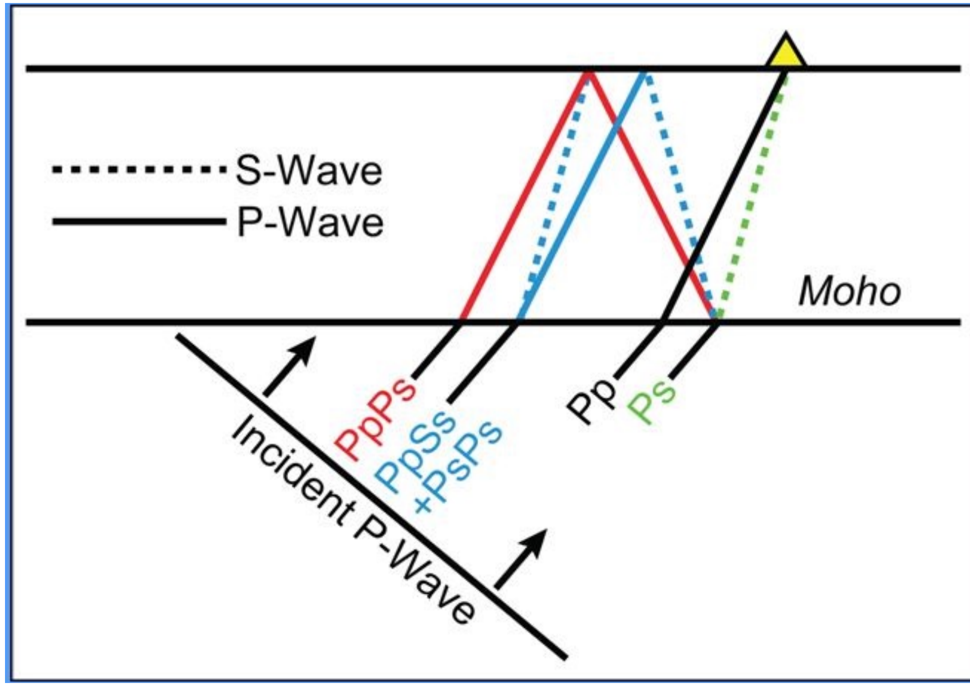
The Receiver Function

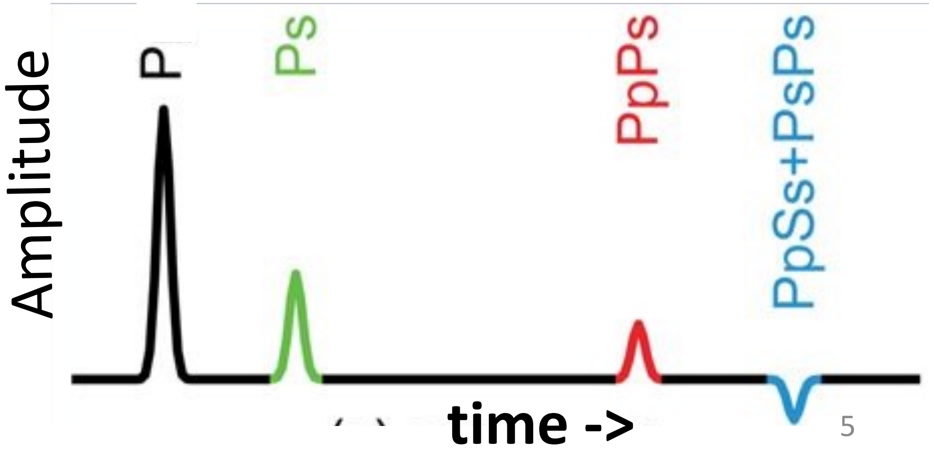
- Time series from 3 component seismograms by deconvolution of horizontal with vertical component
- Provides Earth's structure near the receiver

PRINCIPLE:

- P wave incident on boundary (physical and chemical change take place)
- Converted to S wave and also multiple reflections form
- Converted Phase = Ps, Multiples= PpPs, PpSs

Amplitudes and time modelled to estimate layer thickness and velocity

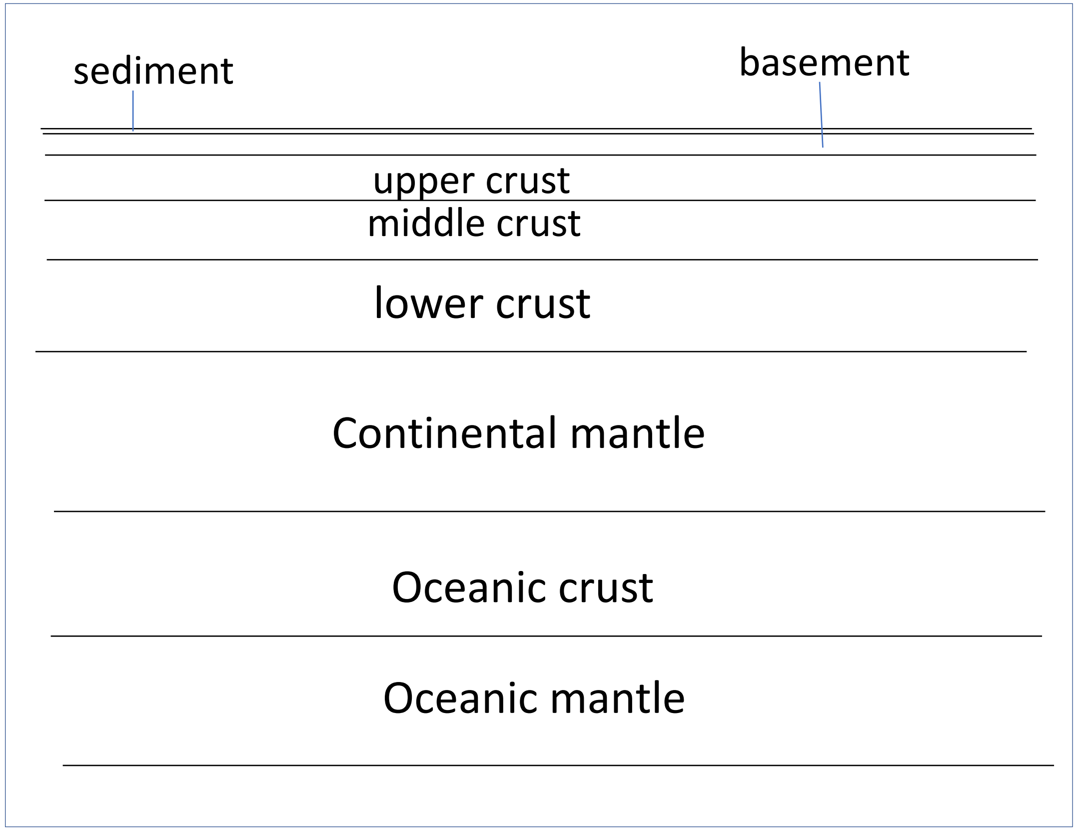




Inversion using Neighbourhood Algirothm (Sambridge, 1999)

- Important for detailed characteristics of crustal velocity
- Velocity parameters at different depths are derived from inversion of receiver functions
- Earth is divided into layers:

sediment, basement, upper, middle and lower crust, upper mantle, slab and mantle

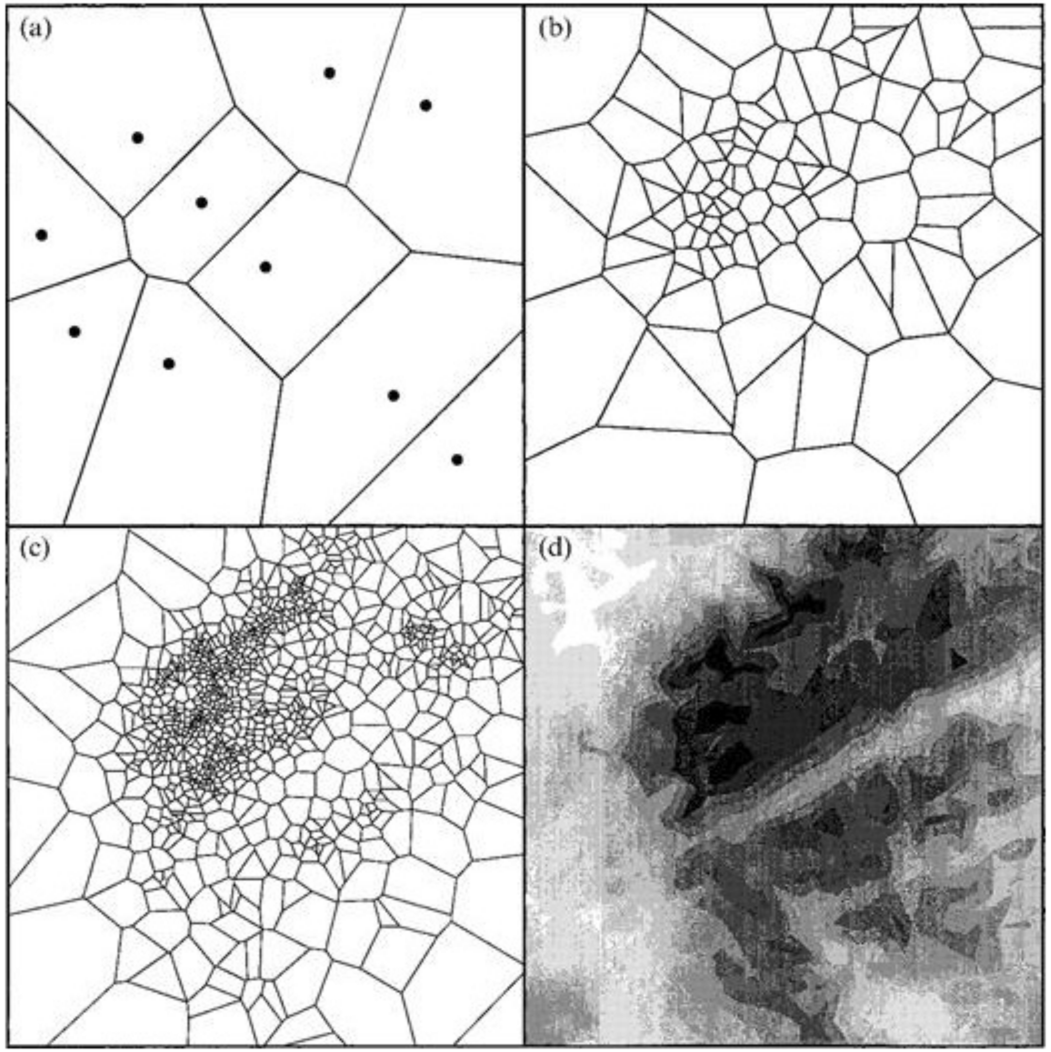


Layer parameters (4)

Thickness of the layer (km)	shear wave velocities at the top and bottom of the layerc	Vp/Vs ratio in that layer

32 dimensional parameter space

Voronoi Cell



Let P = {m1 ,…,mnp } be a set of points of d-space, where 2 ≤ np ≤ ∞, and let mi ≠ mj for i ≠ j. The Voronoi cell about point mi is given by

$$V(\mathbf{m}_i) = \{\mathbf{x} | \, \|\mathbf{x} - \mathbf{m}_i\| \leq \|\mathbf{x} - \mathbf{m}_j\| \quad \text{for } j \neq i, (i, j = 1, \ldots, n_p)\}$$

Voronoi cells of
(a) 10 points
(b) 100 points
(c) 1000 points
(d) Contours of misfit function

Steps in Neighbourhood Algorithm

Generating initial set of ns models in parameter space

↓

for all these models, synthetic receiver functions are constructed

↓

misfit is calculated by defining an objective function, which is the L2 norm of the difference between observed and synthetic receiver function

↓

From these models, nr models were selected with the lowest misfit.

↓

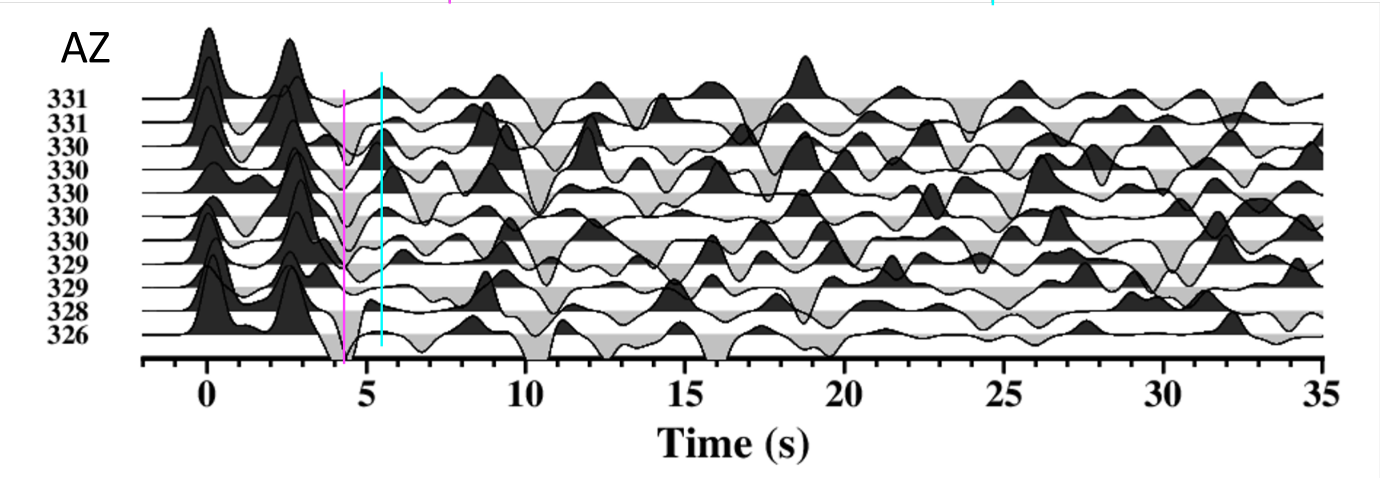
Voronoi cell of each of the nr chosen models (ns/nr models in each cell) is performed to generate ns new models. The process is repeated and more models generated in a region with good fitting areas.

Result from one station

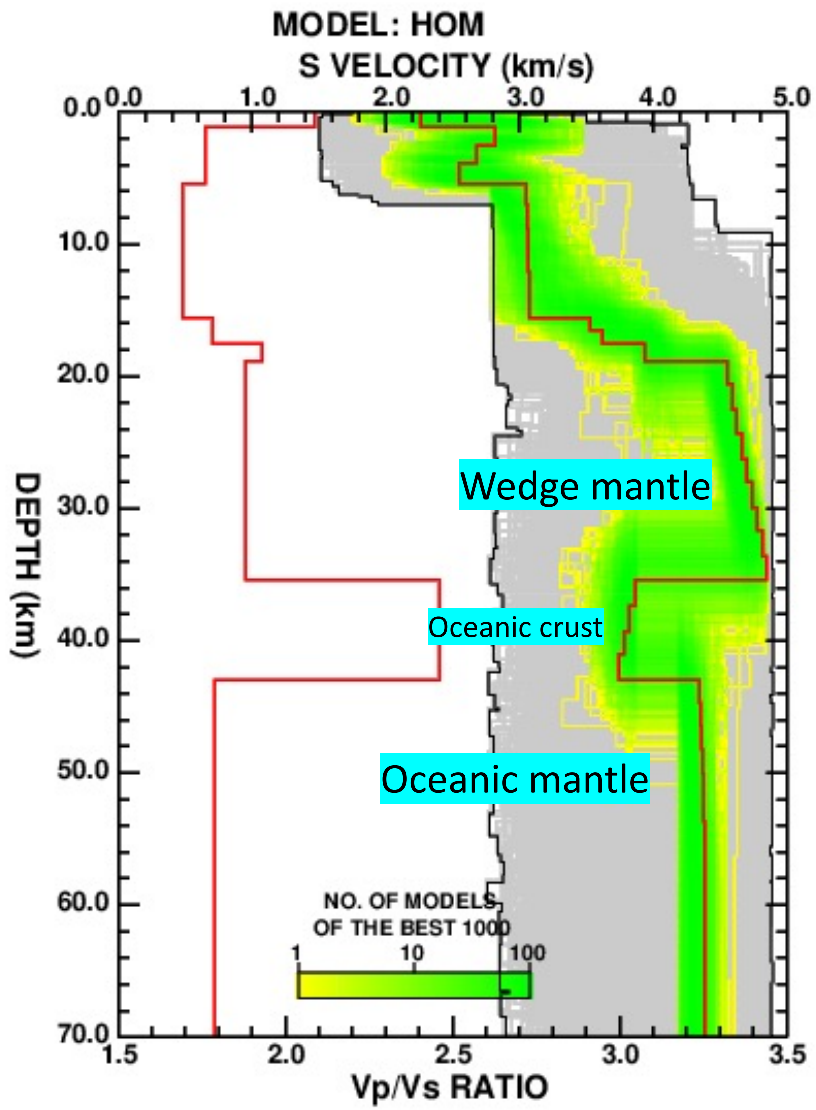
Station HOM selected for stacking and inversion in NW

Phase from top of oceanic slab

Phase from top of oceanic Moho



Absence of intra-crustal phase



Best Vs model

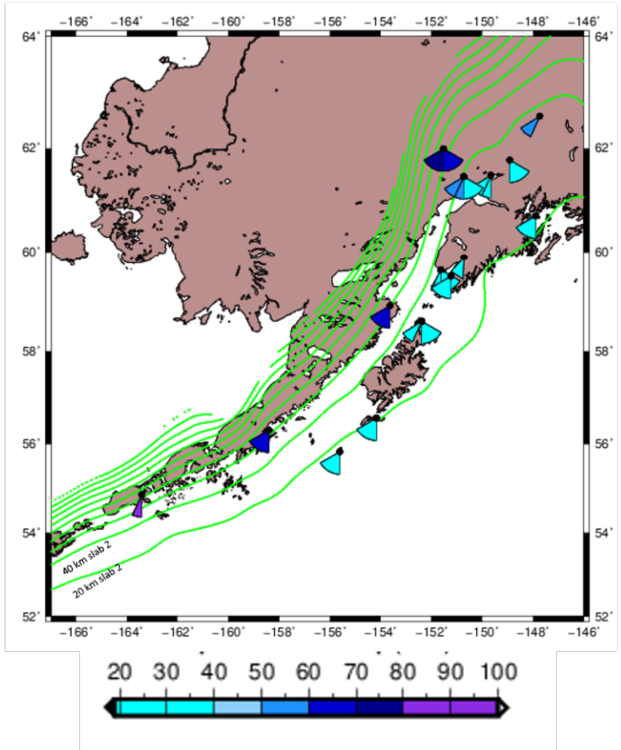
Green to yellow region : Top 100 models

Grey region: All models

The downgoing plate: major interfaces

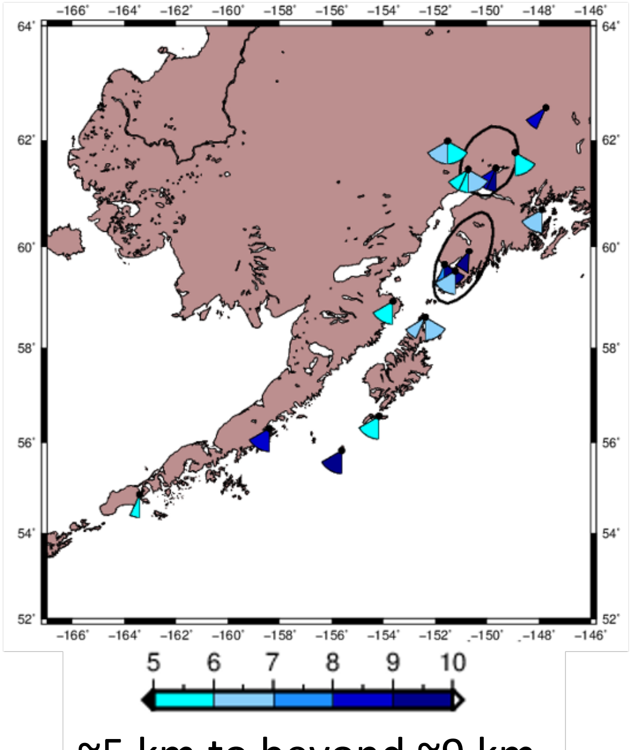
- Black dots : station locations
- Coloured fans : Results in the backazimuth directional segments

Oceanic crust depth (km)



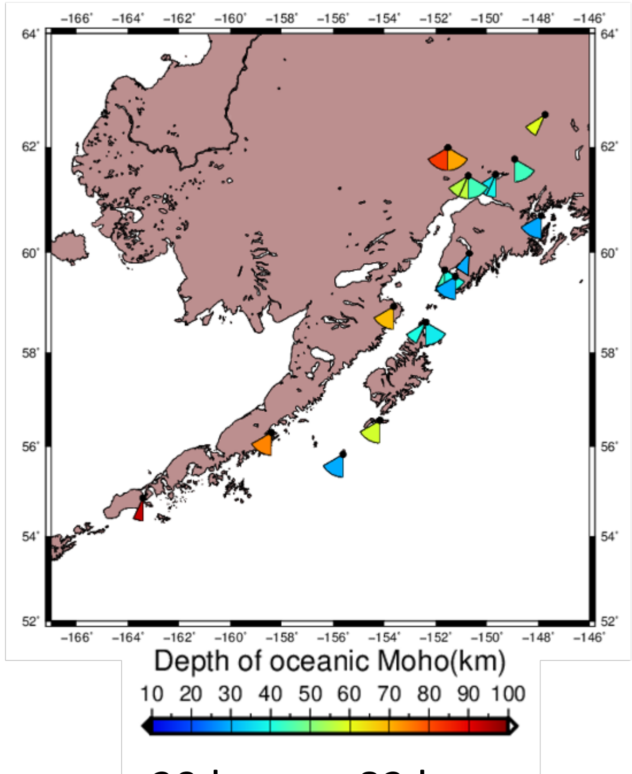
~20 km till beyond ~90 km

Oceanic crust thickness (km)



~5 km to beyond ~9 km

Oceanic Moho Depth (km)

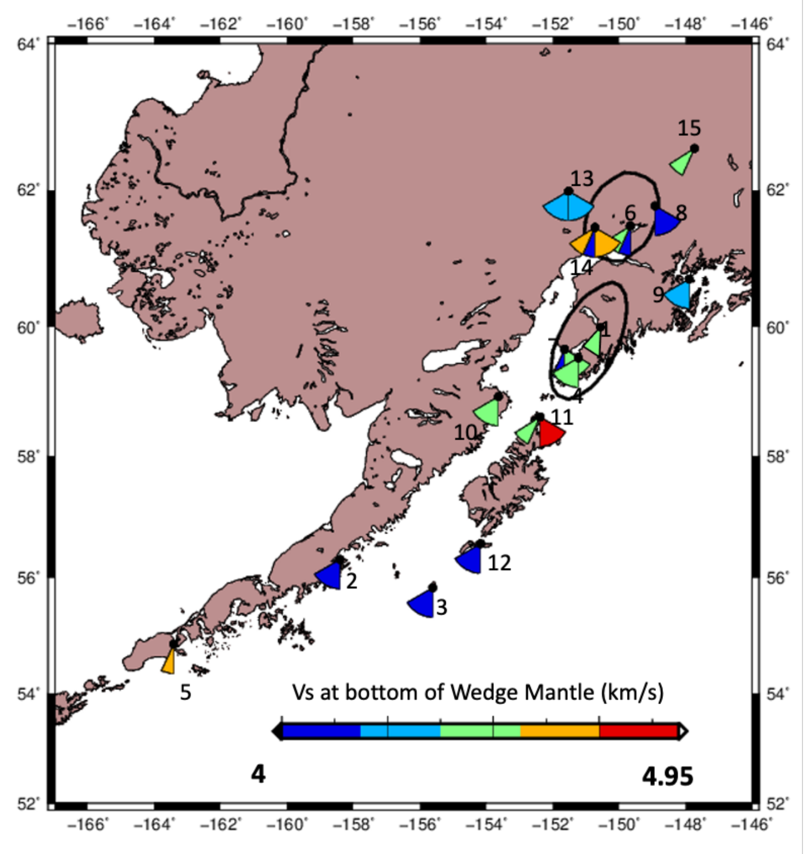


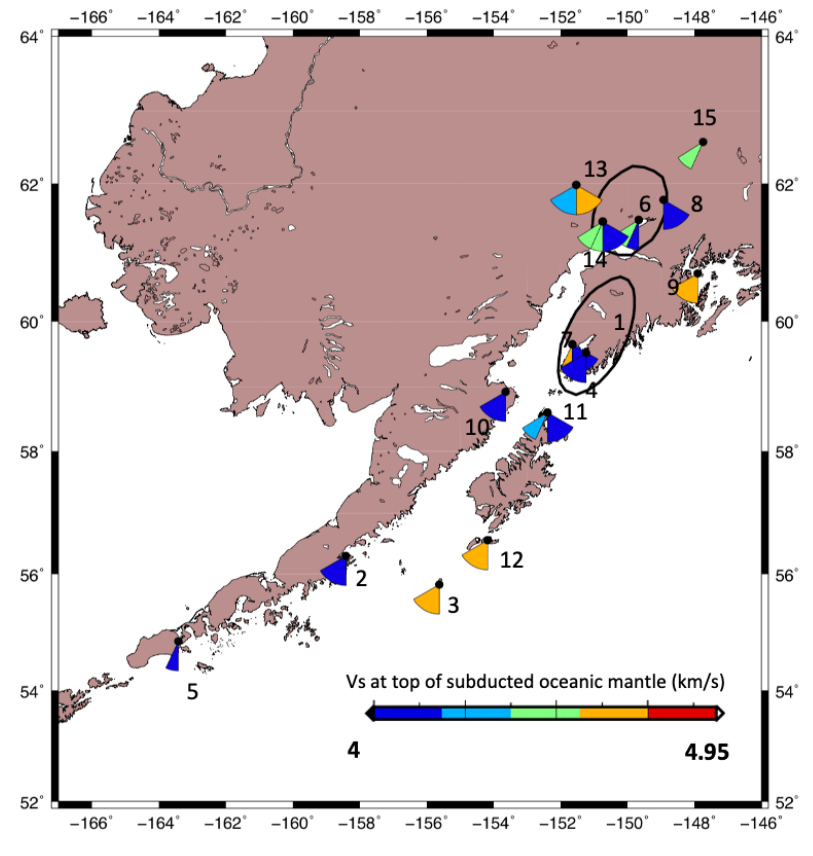
~29 km to ~82 km

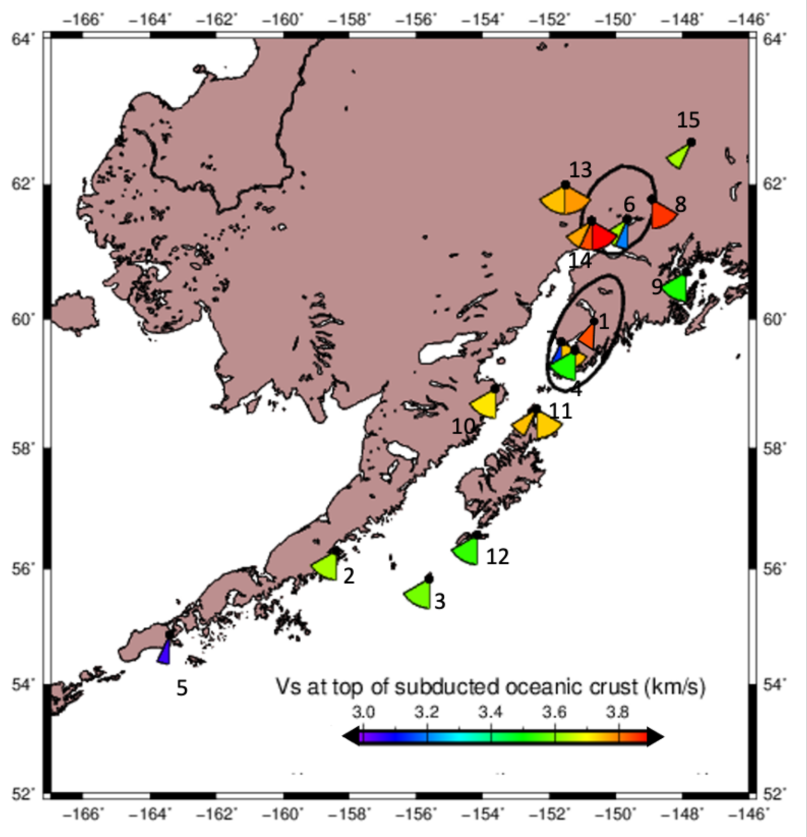
Better correlation with Slab 2 model (Hayes et al., 2018)

Because of dipping and heterogenous structure, value changes for the backazimuth segment

The contact region: Comparing the velocities near the plate interface region







Dominance of lower velocities

Vs range ~4.2 – 4.8 km/s

Vs range ~4.0 – 4.7 km/s

- Interesting trend of Vs observed towars slow slip with exceptions
- Blue -> Green -> Yellow -> Red towards NE

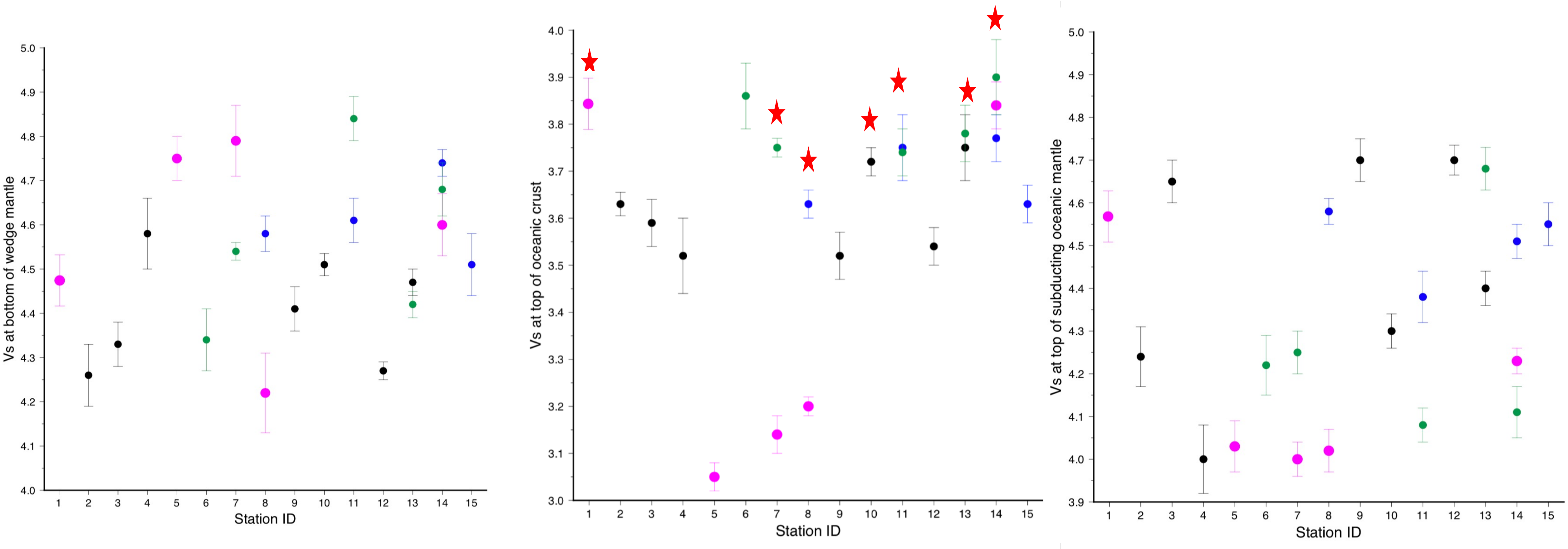
Vs range ~3 – 3.9 km/s

Berg et al. (2020) : found mantle velocities ~45 km.

- Low velocities related to tectonics, Yakutat and Pacific subduction
- Christeson et al. (2010) : Yakutat originated as oceanic plateau
- Supports high Vp/Vs by Zhang et al. (2019)

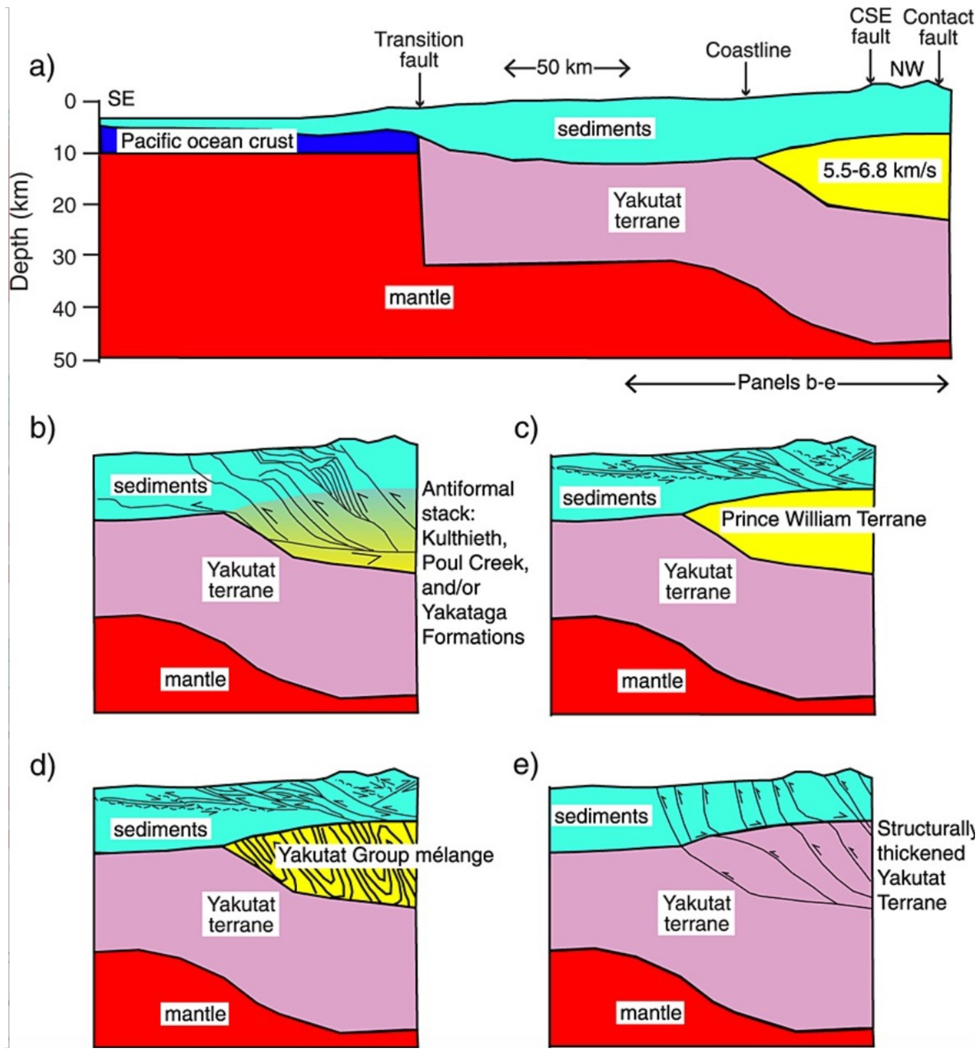
Pacific subducts beneath Yakutat (NE): Christeson et al. (2013)- velocity high

Error analysis – bootstrap and sensitivity analysis



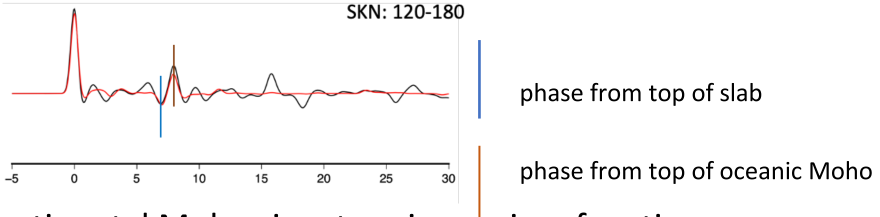
★ High values for stations closer to slip areas (with exceptions)

Influence of sediment balance on overall structure

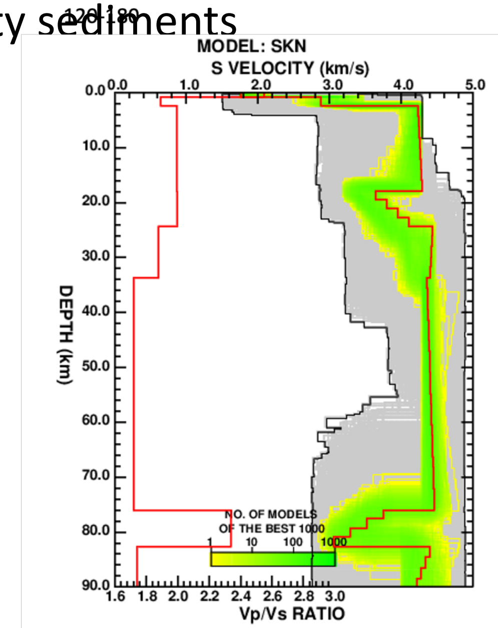


Christeson et al., 2013

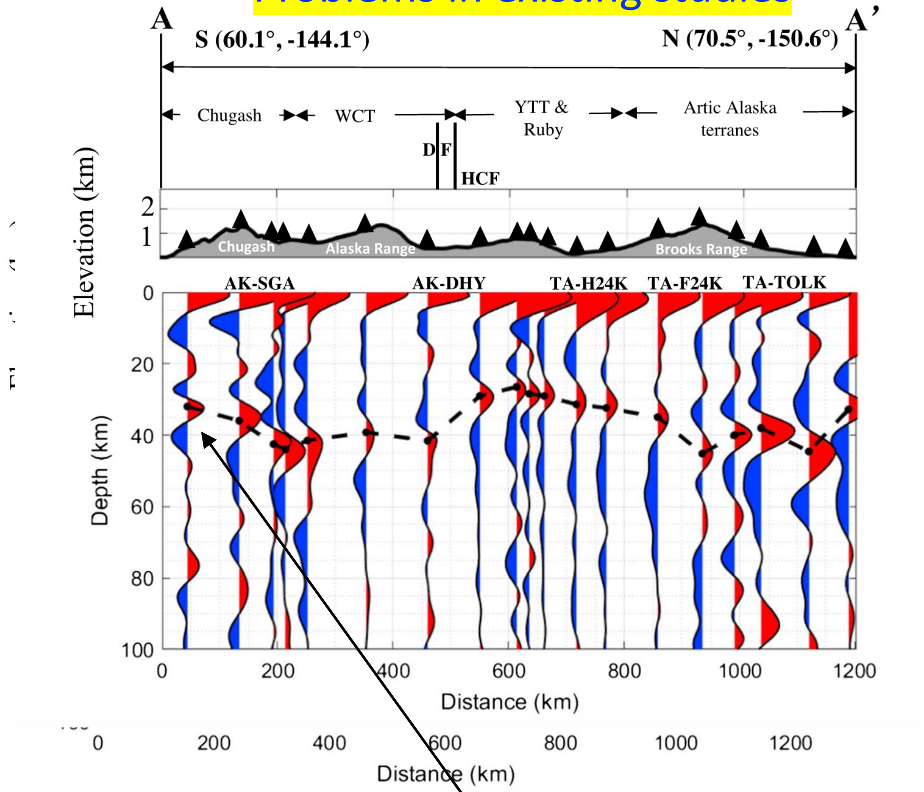
- Large accretionary wedges in the subduction thrust settings (Von Huene and Scholl, 1991)
- The slab material can accumulate due to frontal accretion or by underplating of materials (Platt, 1989)
- Sediment subduction also dominates that leads to loss of material from the upper plate, known as subduction erosion (Von Huene and Scholl, 1991)
- Possibly reduce the evidence of continental Moho signature
- Christeson et al. (2013) argued that compacted sediments under certain conditions leads to high velocity sediments beneath the subsurface structure.
- Slab materials transported
- Wide range of crustal velocities

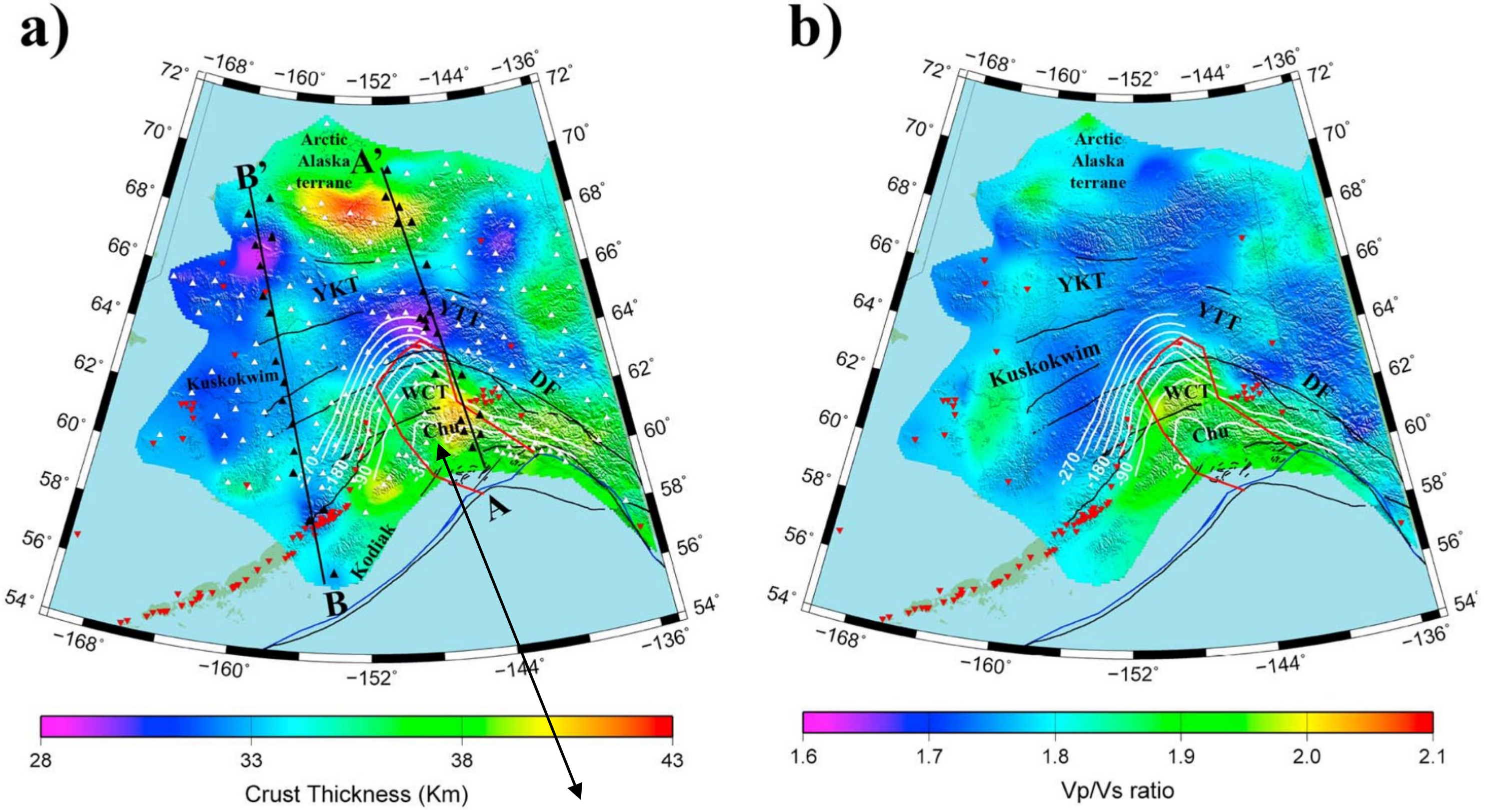


No continental Moho signature in receiver function



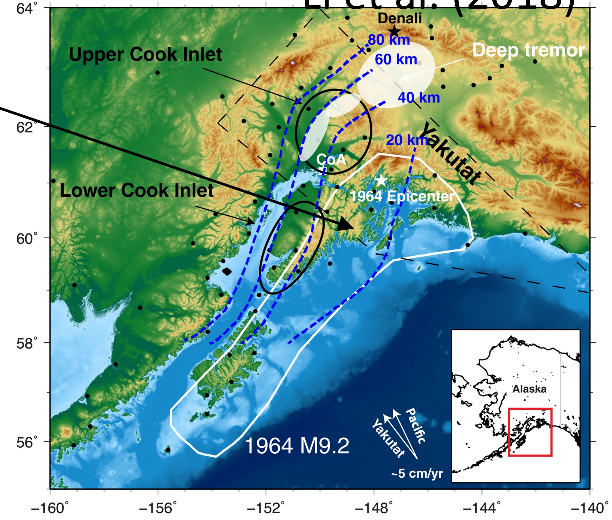
Problems in existing studies





If slab is 25 km, crustal thickness cannot be ~35 km.

Li et al. (2018)



Zhang et al. (2019) : Crustal Thickness, Vp/Vs ratio –closer to the subduction arc realistic?

Berg et al. (2020) Southern Alaska positive may not be positive Moho phase

Discrepancy for region along the subduction forearc

They are mapping the oceanic Moho instead of continental one towards coast.

This study : Better estimation of plate interface properties close to the subduction arc for slow slip study.

Key observations from Alaska

EGU General Assembly 2022

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Estimation of properties of the upper lithosphere along Alaska-Subduction forearc:

- The oceanic crust depth varied from ~20 km - ~80 km, oceanic crust thickness varied from ~5km -~9 km, oceanic Moho ~25 km – 80 km; We find the velocities in the lower wedge mantle ranges from ~4.2 - 4.8 km/s, in the top of subducted oceanic crust from ~3 – 3.9 km/s and in the upper part of subducted oceanic mantle from ~4 – 4.7 km/s.

- In the plate interface region, the velocities of both the mantle wedge bottom and top of oceanic mantle dominated the lower range. This could be related to subduction of the two oceanic crusts, the Pacific plate and the Yakutat terrane. The velocities at the top of the oceanic crust were heterogenous, with appearance of higher velocities approaching towards the Cook Inlet region. Interestingly, this region coincides with the slow slip.

- Dominance of flat slab, subduction of Pacific slab and Yakutat slab affect the plate interface velocities.

- We also found some of the high velocities in the crustal forearc region that could be due to sedimental accretion and/or underplating, that diminish the Moho signature in the region.

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Thanks for listening !