Revisiting 50 years of ISC data: Worldwide improvement in earthquake locations and seismic monitoring capabilities

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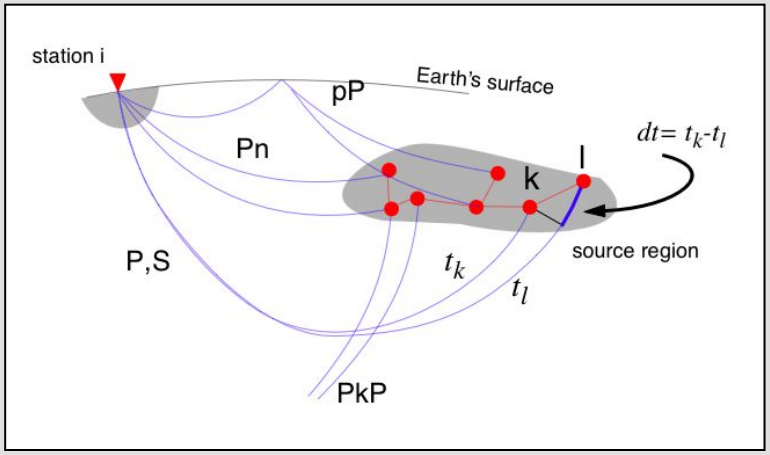
IUGG Prague, June 27, 2015

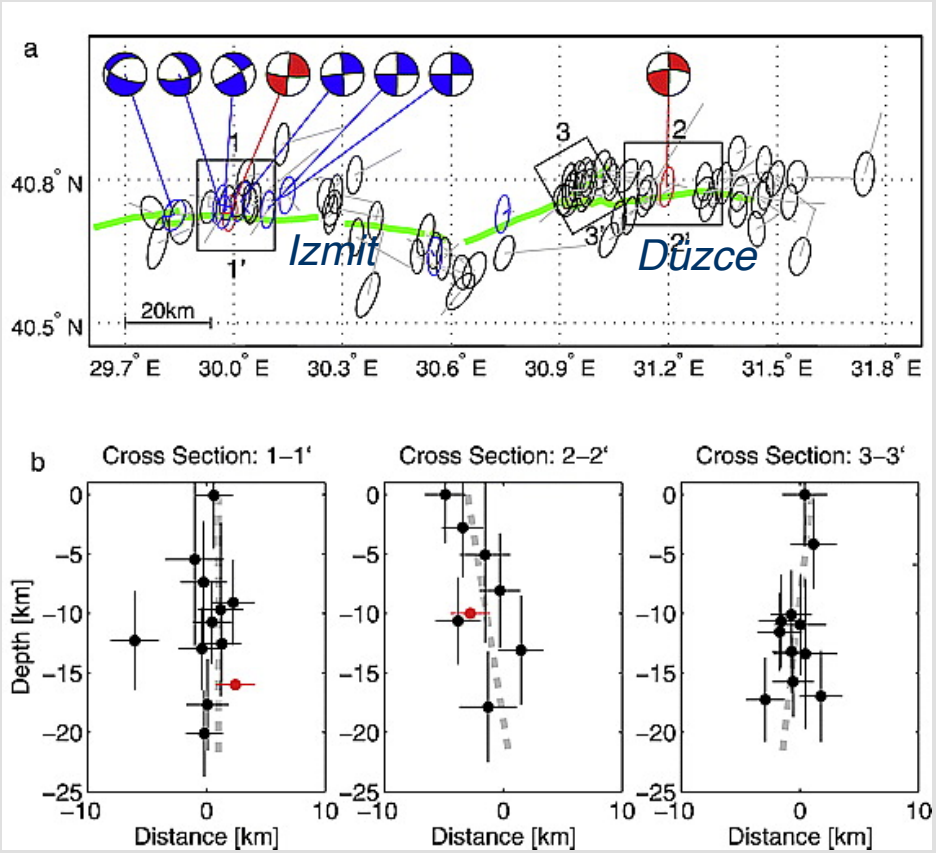
Outline

- Motivation for an ISC catalog relocation effort
- Procedures for **global-scale double-difference** hypocenter relocation
- Initial results and the case for continuing ISC efforts

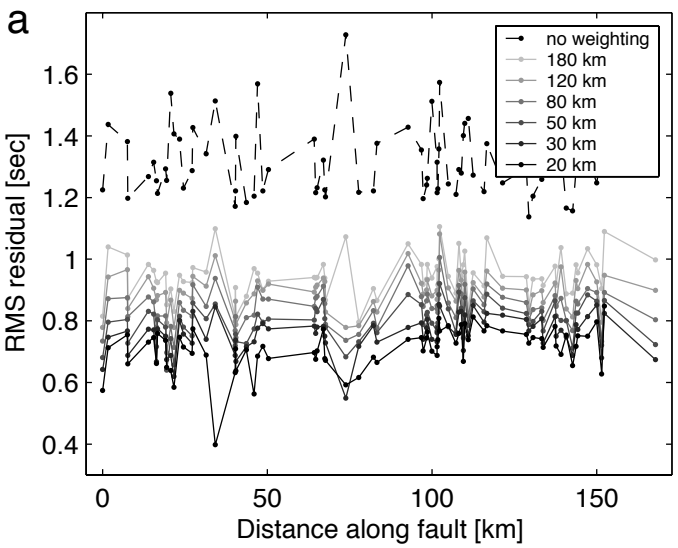
Teleseismic DD studies –
1999 Izmit/Düzce Mw 7.4 sequence



Regional aftershock relocations:



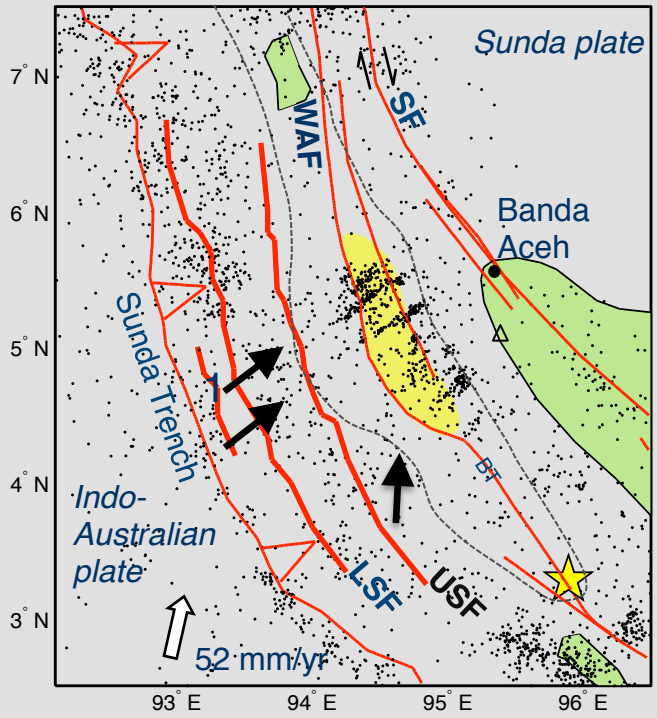
DD distance weighting:



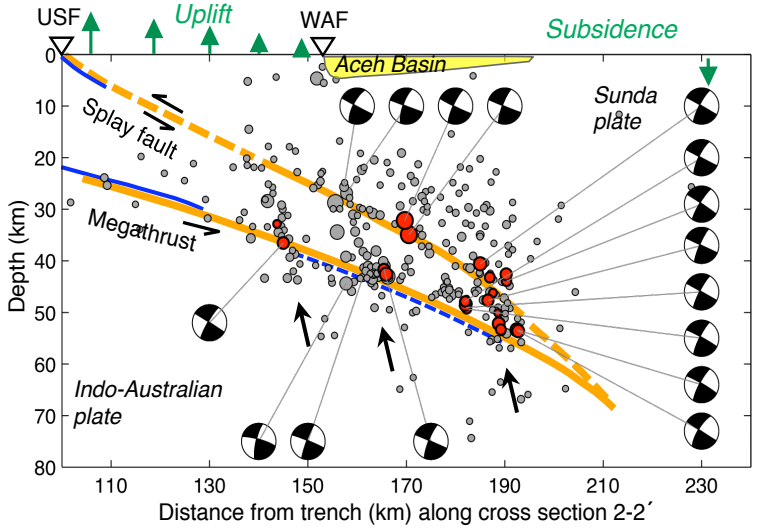
- Teleseismic, multi-phase HypoDD algorithm

Waldhauser and Schaff (JGR 2007)

Streaking aftershocks off-shore northern Sumatra

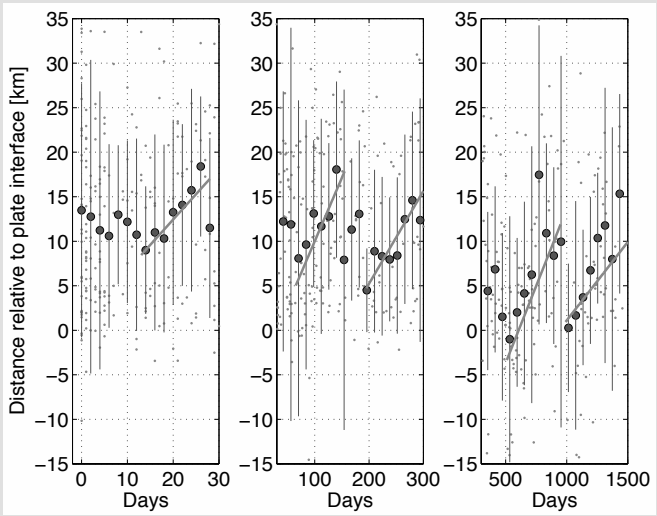


Depth section, looking NW:



1. Fluids expelled from oceanic crust cause failure of imbricate faults.
2. Aftershock streaks controlled by inherited sea floor fabric.

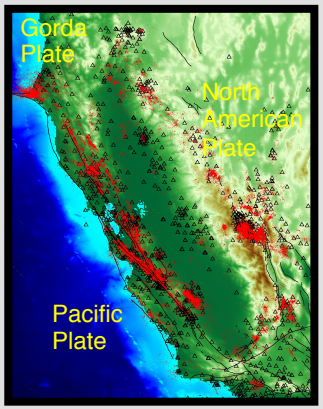
➔ *Improved spatial resolution reveals temporal signals.*

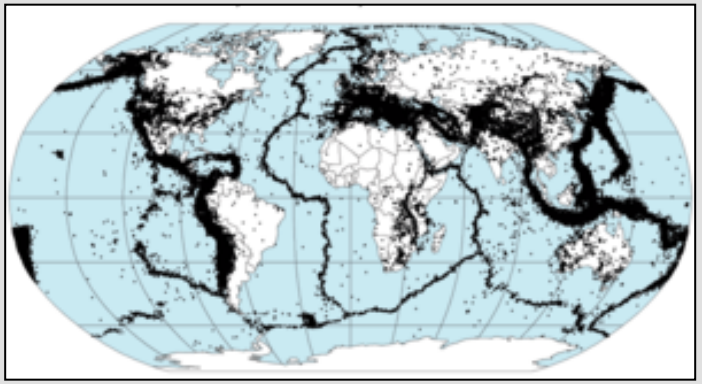


Waldhauser et al (2012)

Scaling up from *regional* to *global* DD processing

We combined double-difference procedures developed for ***massive-scale*** regional catalog and ***real-time*** relocation in California with those developed for specialized ***teleseismic*** applications.





- Northern California

Catalog relocation (1984-present)

- Seismographs……..900
- Events……..……532,000
- Seismograms……20,000,000
- Phase readings…….....10,000,000

Real-time: http://ddrt.ldeo.columbia.edu
http://www.ncedc.org/ncedc/

- The world (ISC, EDR, IRIS)

Archive since ~1960

- Seismographs……18,000
- Events……..…. 3,000,000
- Seismograms……200 Tb
- Phase readings…….....100,000,000

Global DD (gDD) processing

Steps for reprocessing the combined archives of the ISC, EDR, EHB, and IRIS, including 3 million earthquakes.

① Establish baseline catalog ➔ *EHB-DD*

② Fix large location errors in ISC catalog: relocate each ISC event relative to the baseline using the DDse algorithm ➔ *ISC-DDse*

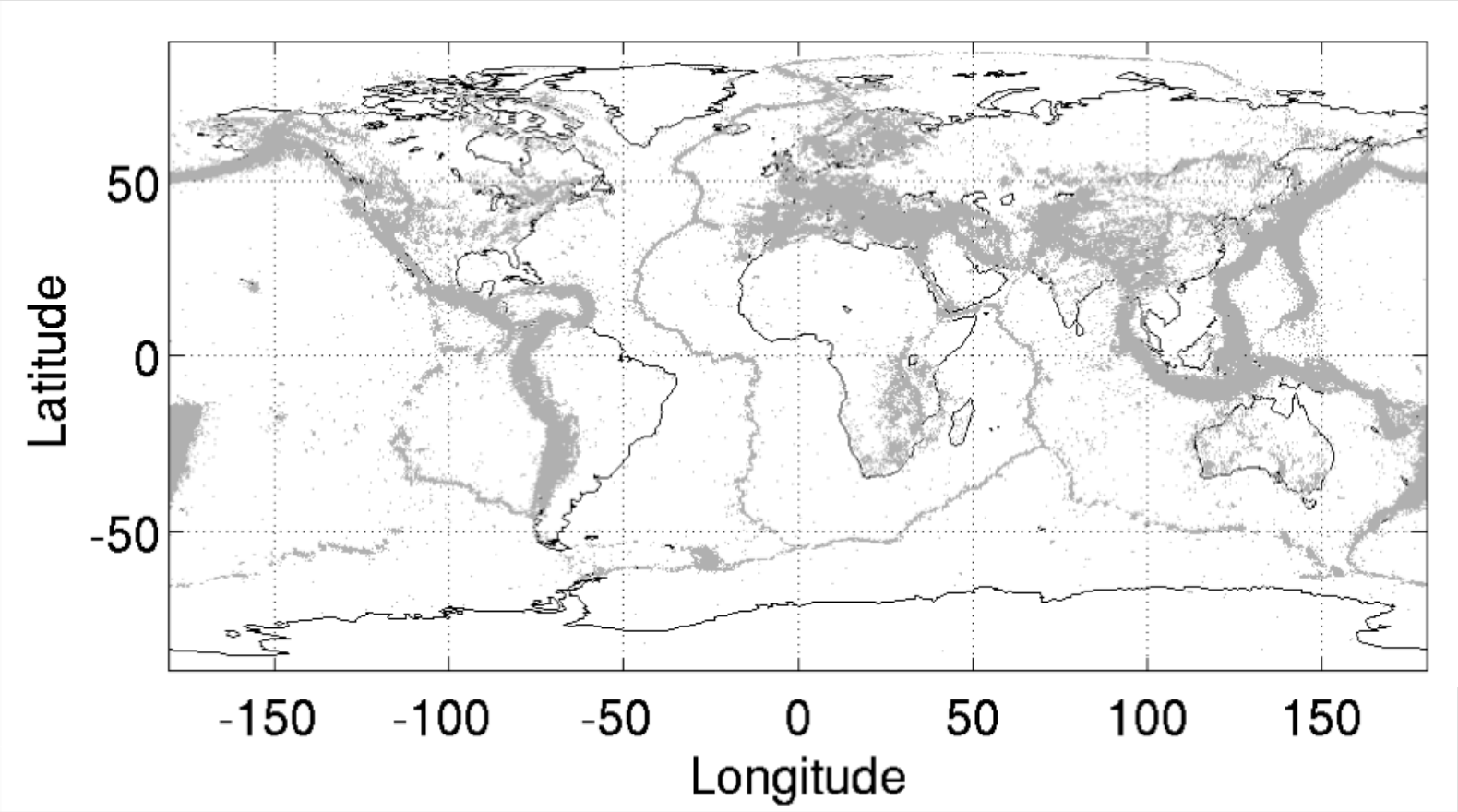
③ Simultaneous DD inversion of *ISC-DDse* catalog ➔ *gDD*

④ Cross-correlate waveforms for nearby events.

⑤ Simultaneous DD inversion of combined pick and correlation delay times ➔ final *gDD* catalog.

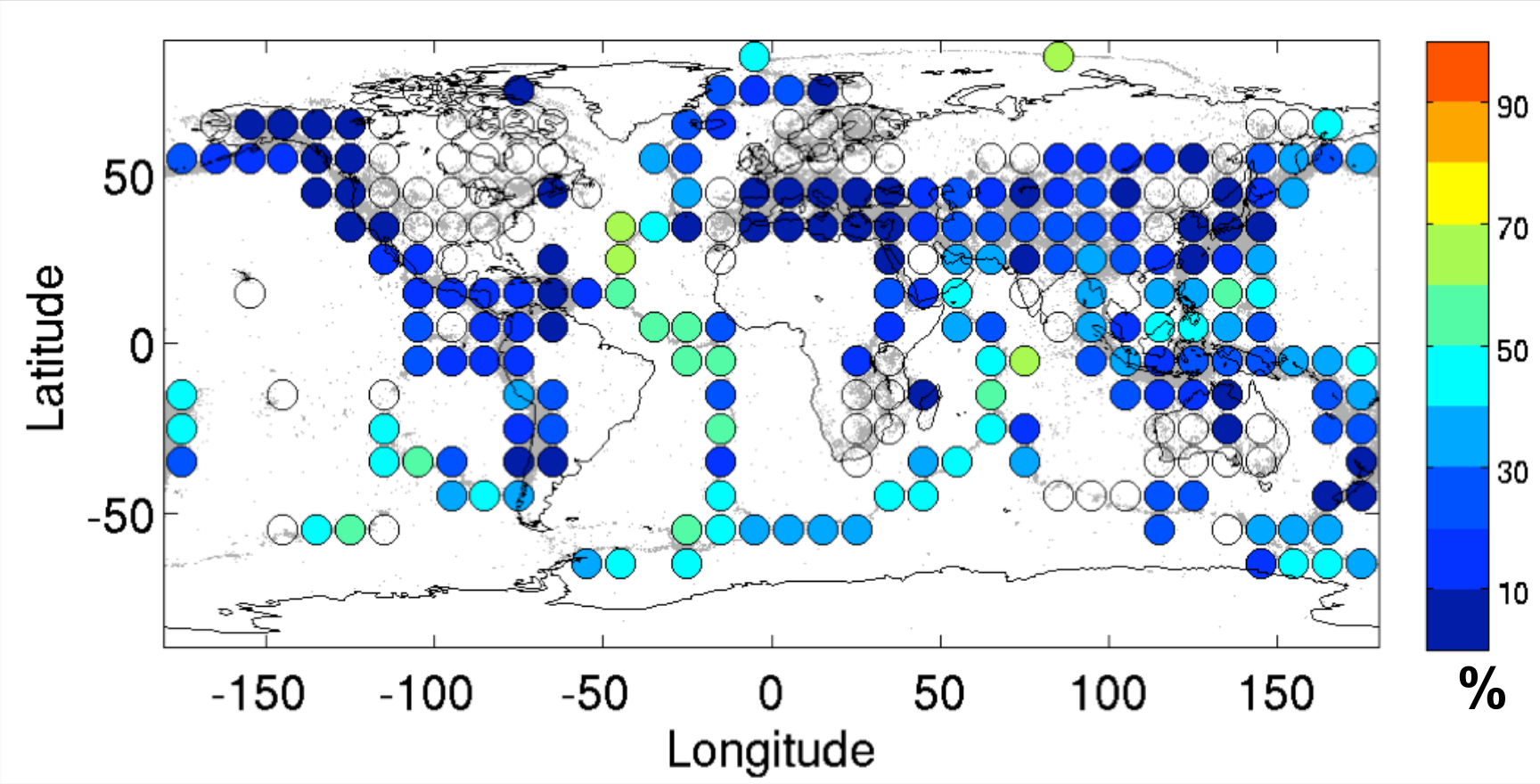
⑥ Use gDD catalog for real-time operation ➔ *gDD-RT*

ISC-EDR (1960-2012)



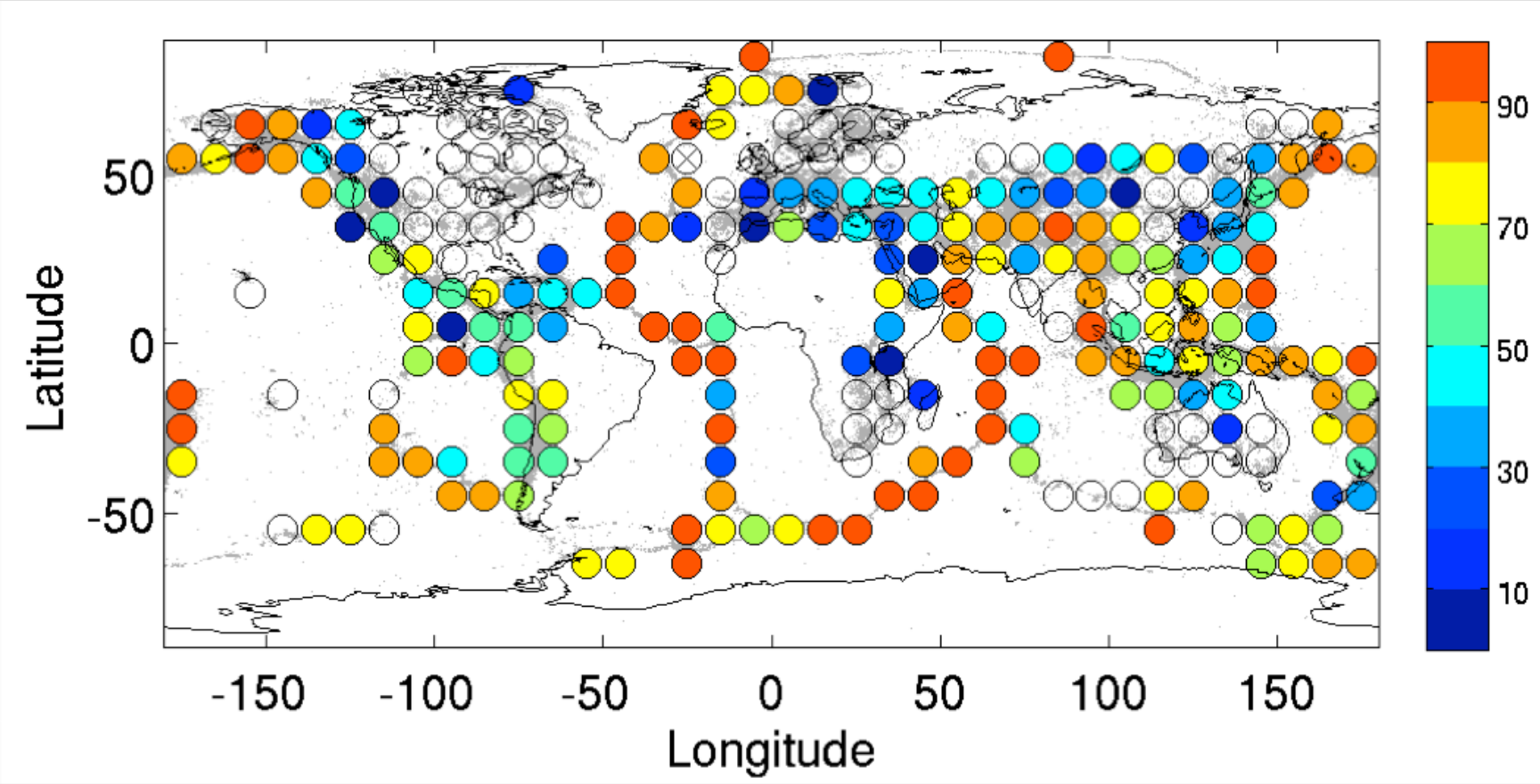
- Total ISC/EDR (10+ stations)……1,800,000 events

EHB catalog (double-differenced)



- Total ISC/EDR (10+ stations)……1,800,000 events
- EHB relocated……132,000 events

gDD catalog (current status)

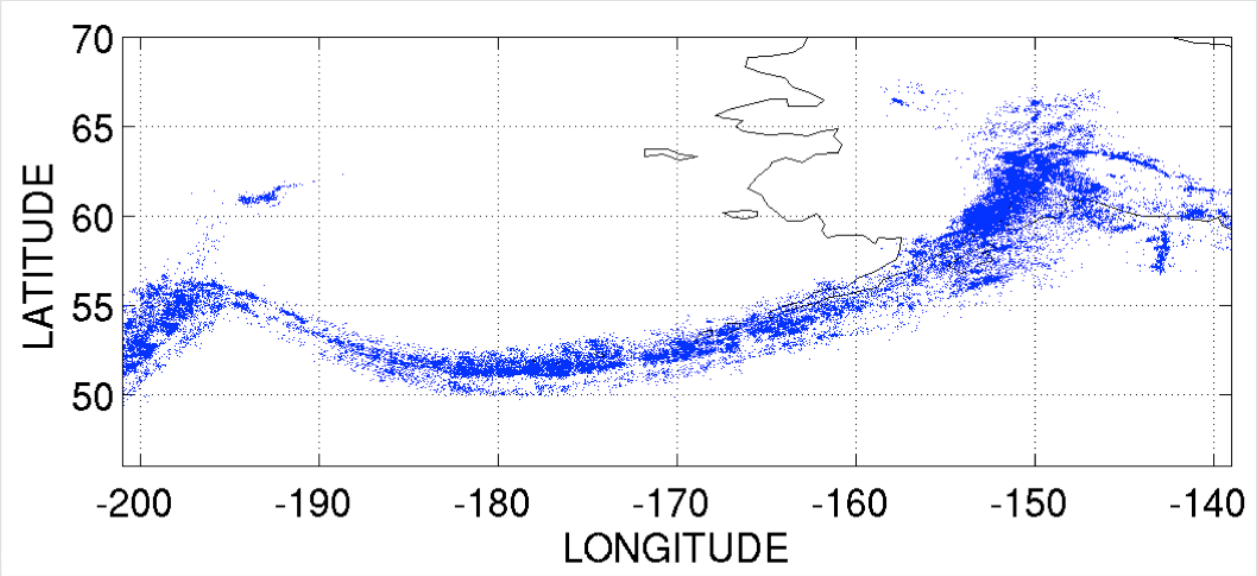


- Total ISC/EDR (10+ stations)……1,800,000 events
- EHB relocated……132,000 events
- gDD (2 x DDse + DD)……820,000 events

gDD results – Aleutian relocations

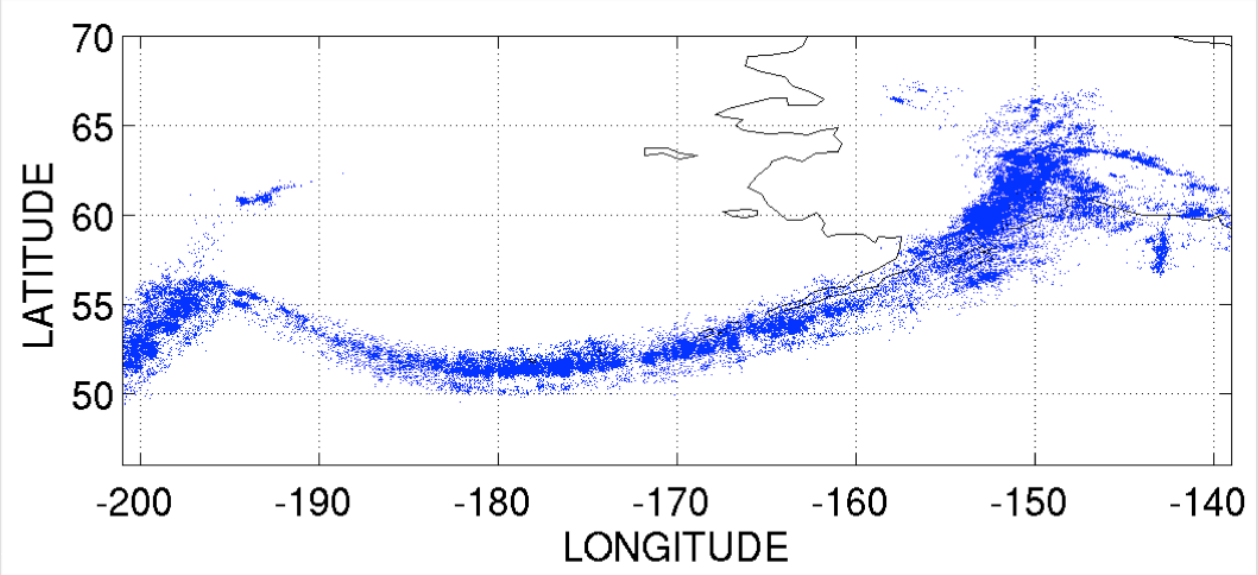
gDD
(picks only)

RMS = 0.6s

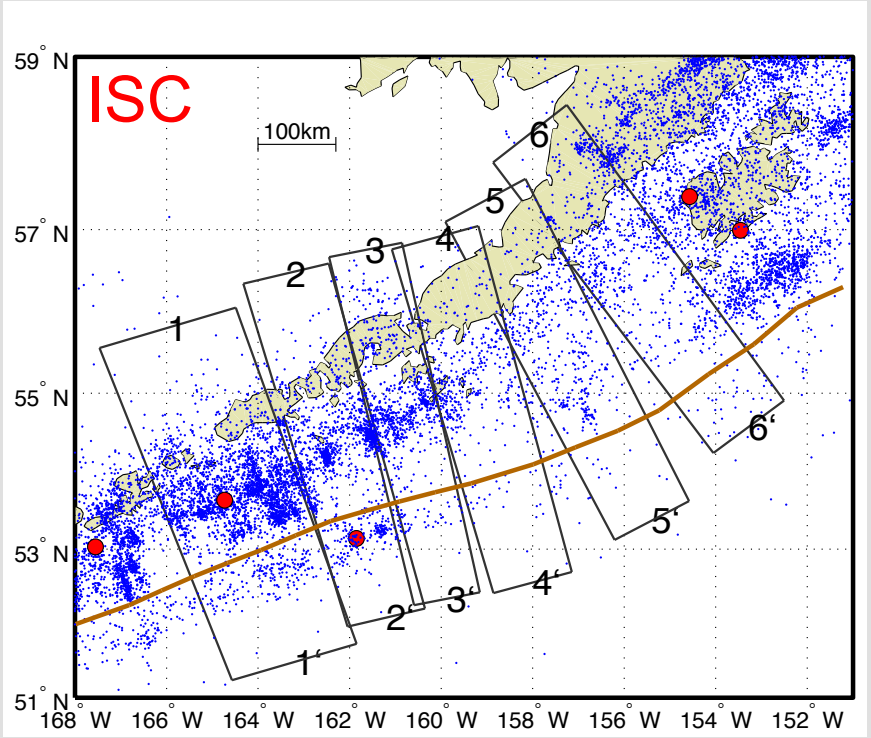


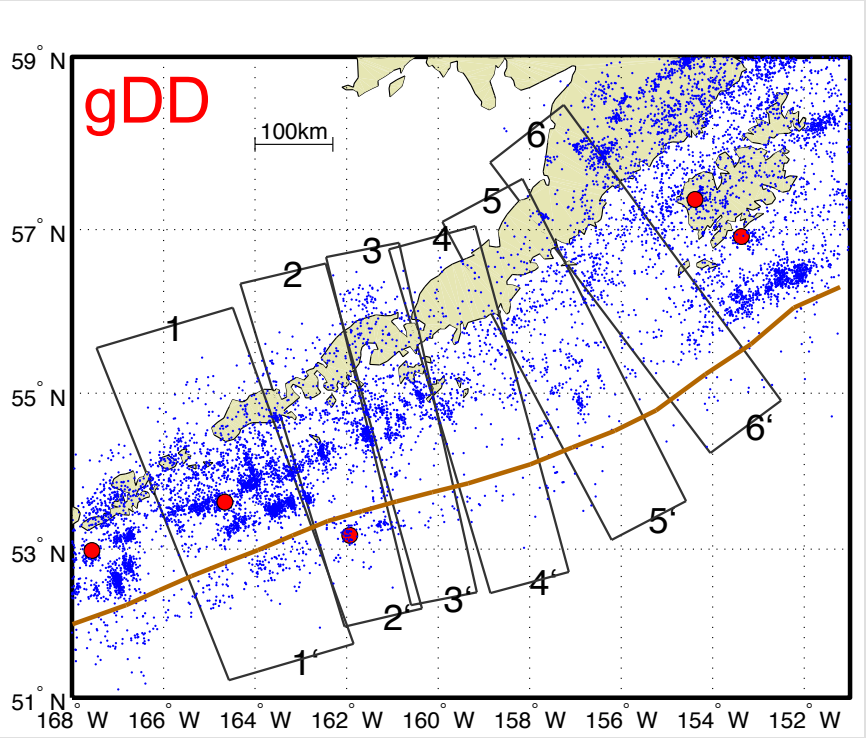
ISC

RMS= 1.1s

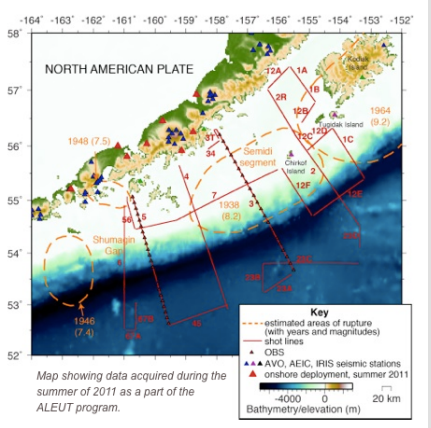


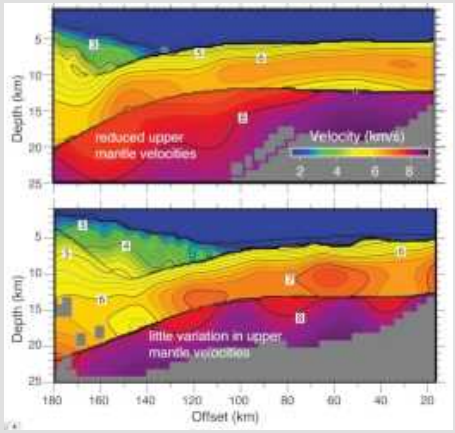
Southern Alaska





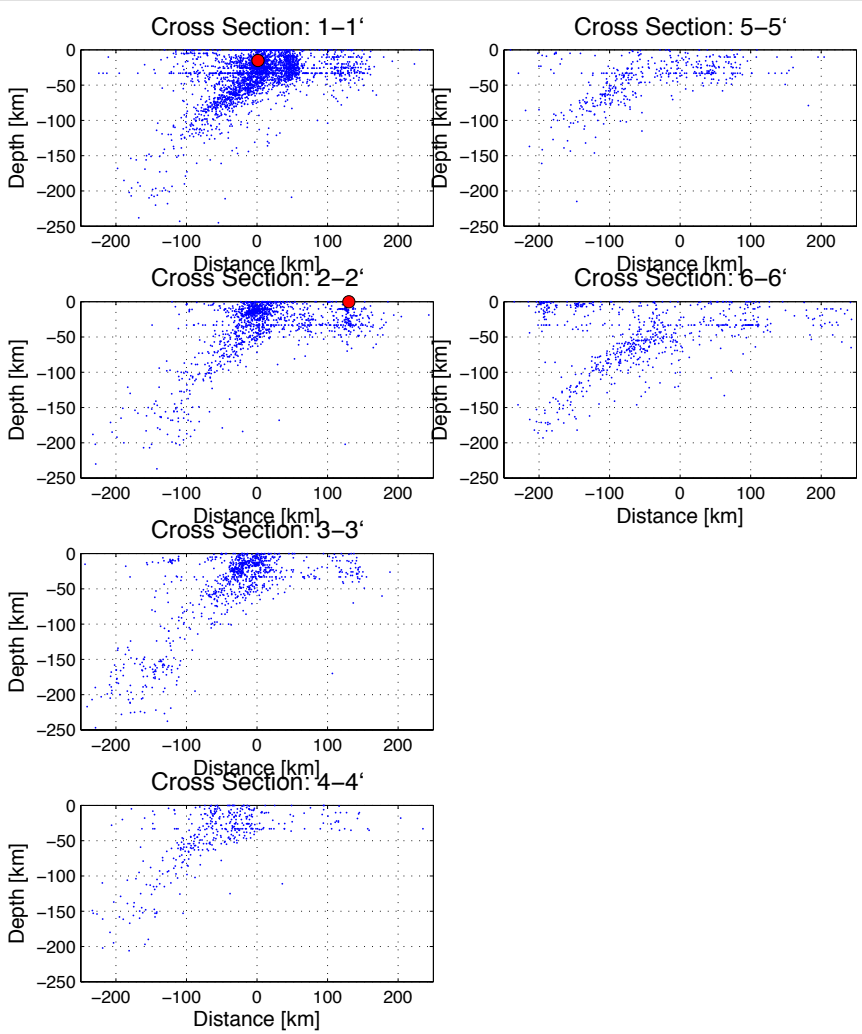
- ALEUT active source data (Shillington et al., 2015)
- USArray



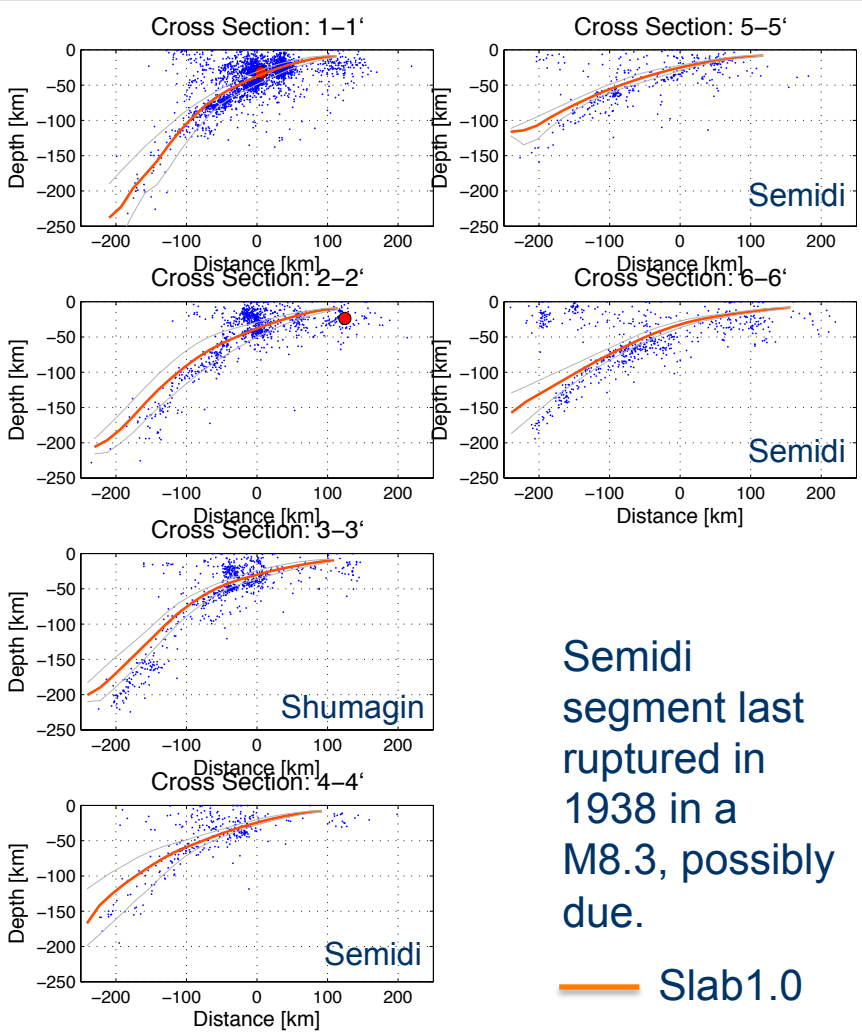


Southern Alaska

ISC



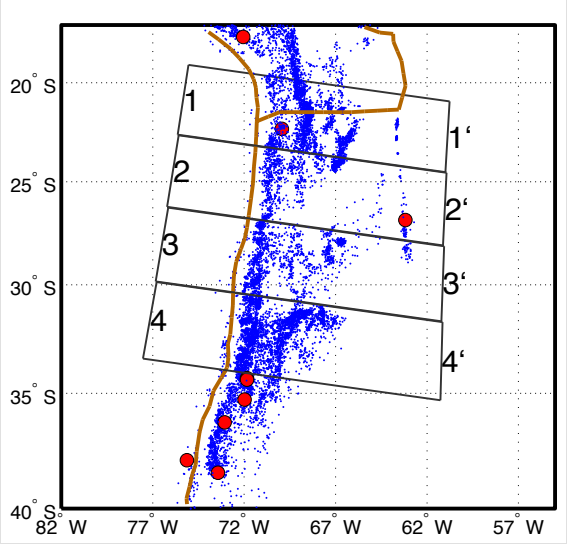
gDD



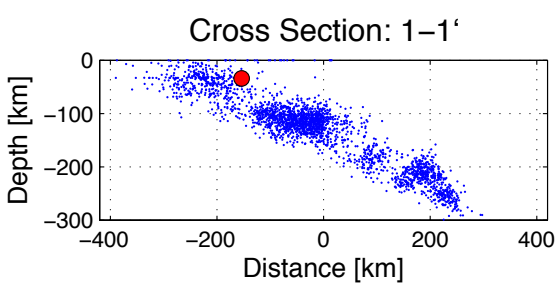
Semidi segment last ruptured in 1938 in a M8.3, possibly due.

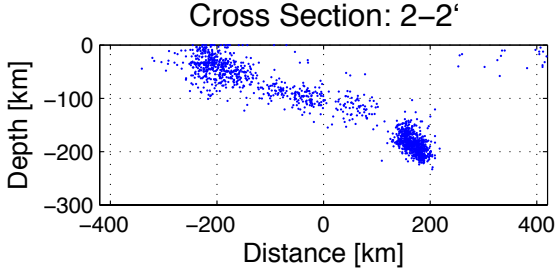
Slab1.0

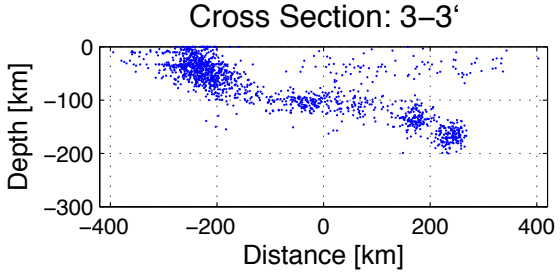
South America

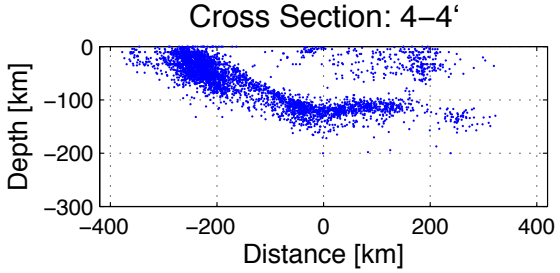


ISC

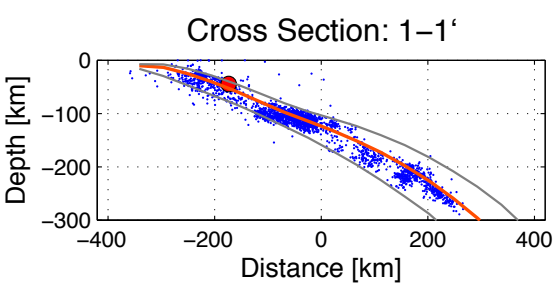


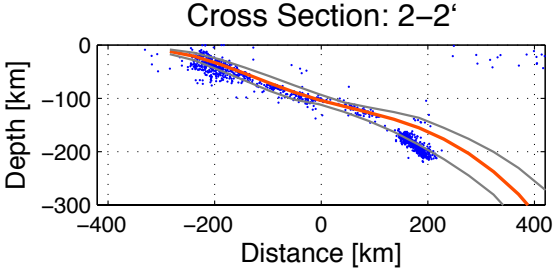


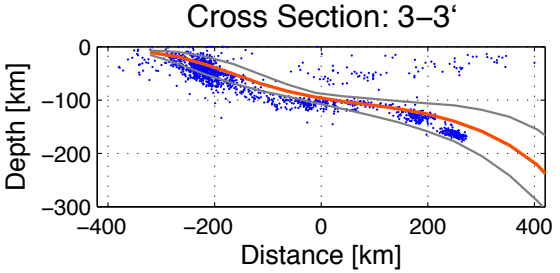


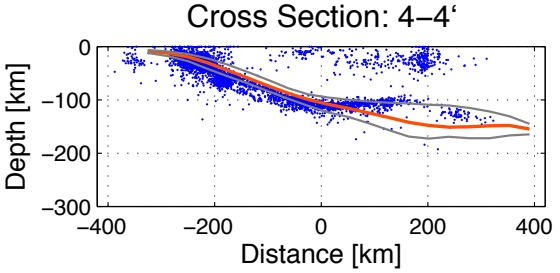


gDD

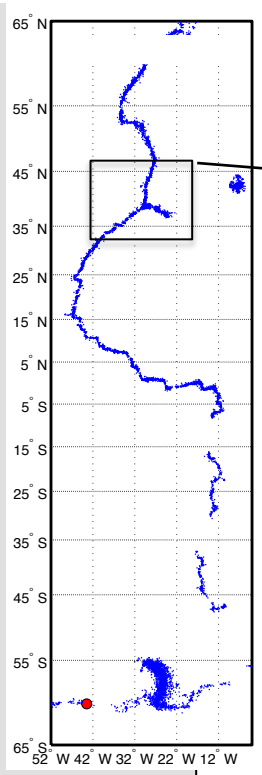


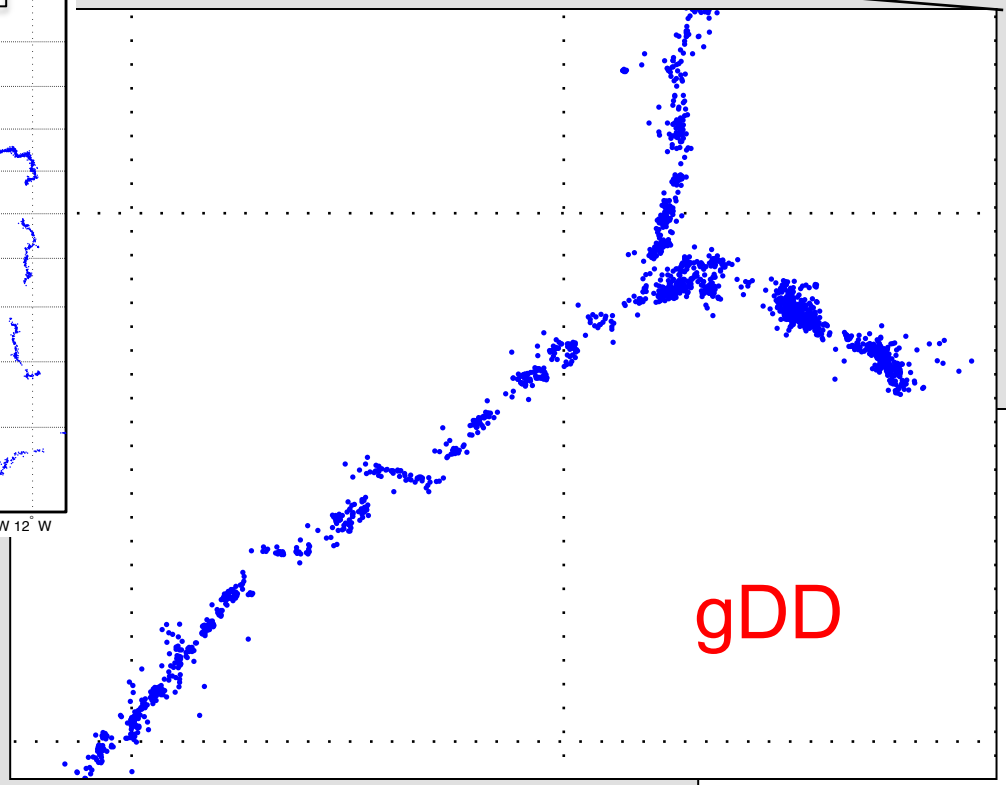


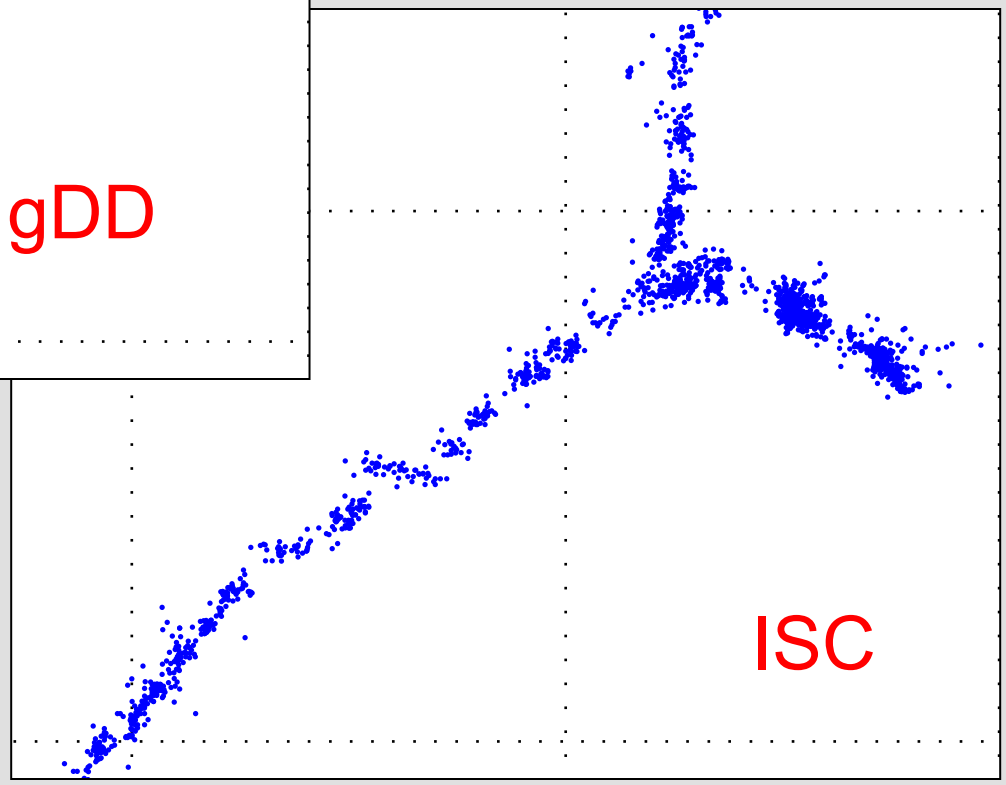




Mid Atlantic Ridge

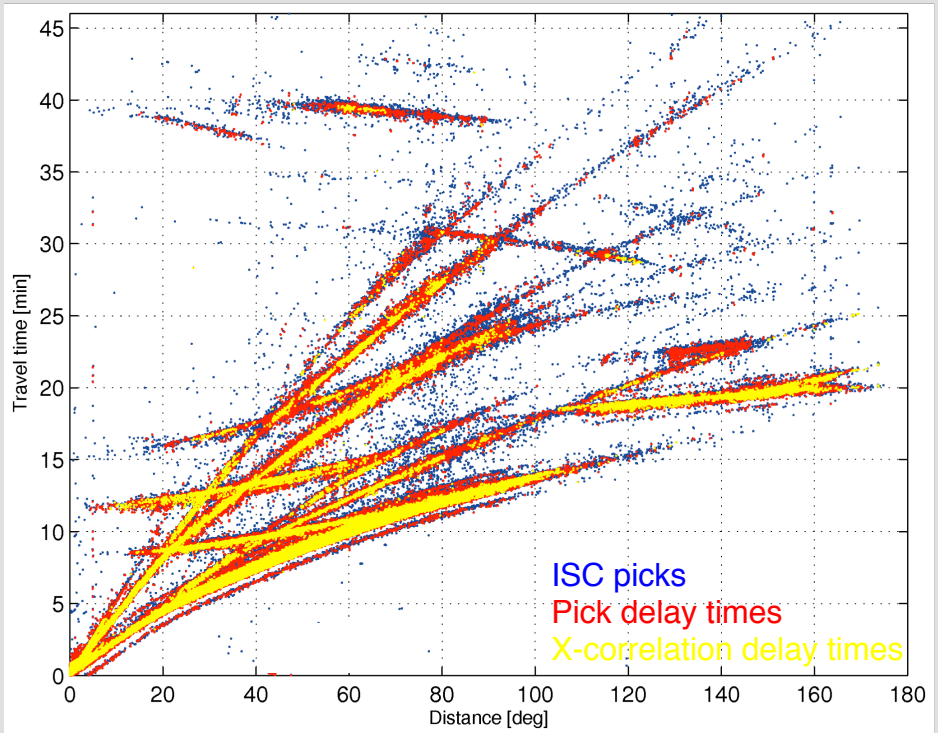






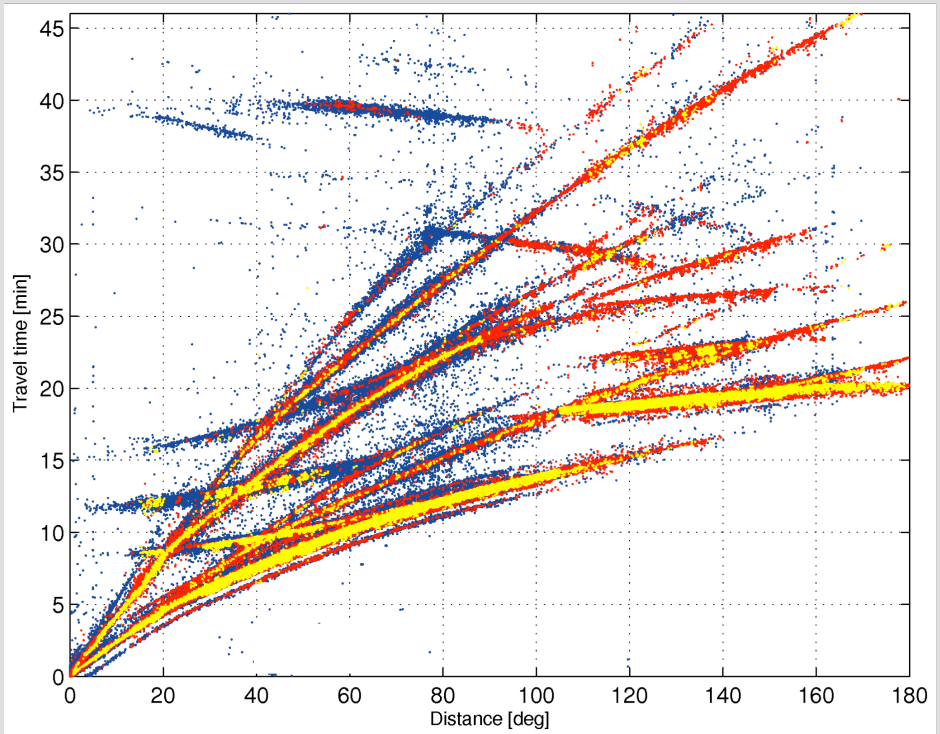
Initial waveform cross-correlation results

Aleutian Arc



- ~30 million, 60,000 events
- Windows: 7/8 sec
- Filter: 0.5-2 Hz
- Correlation coefficient: > 0.4

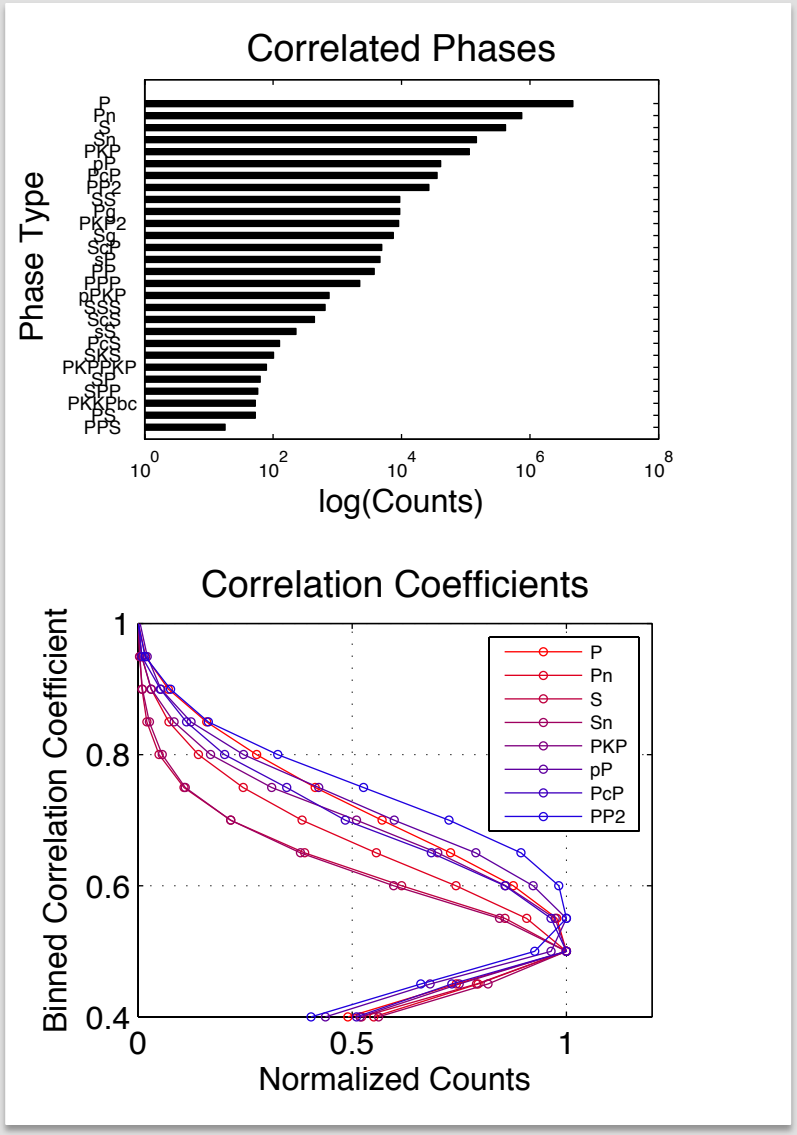
Mid Atlantic Ridge



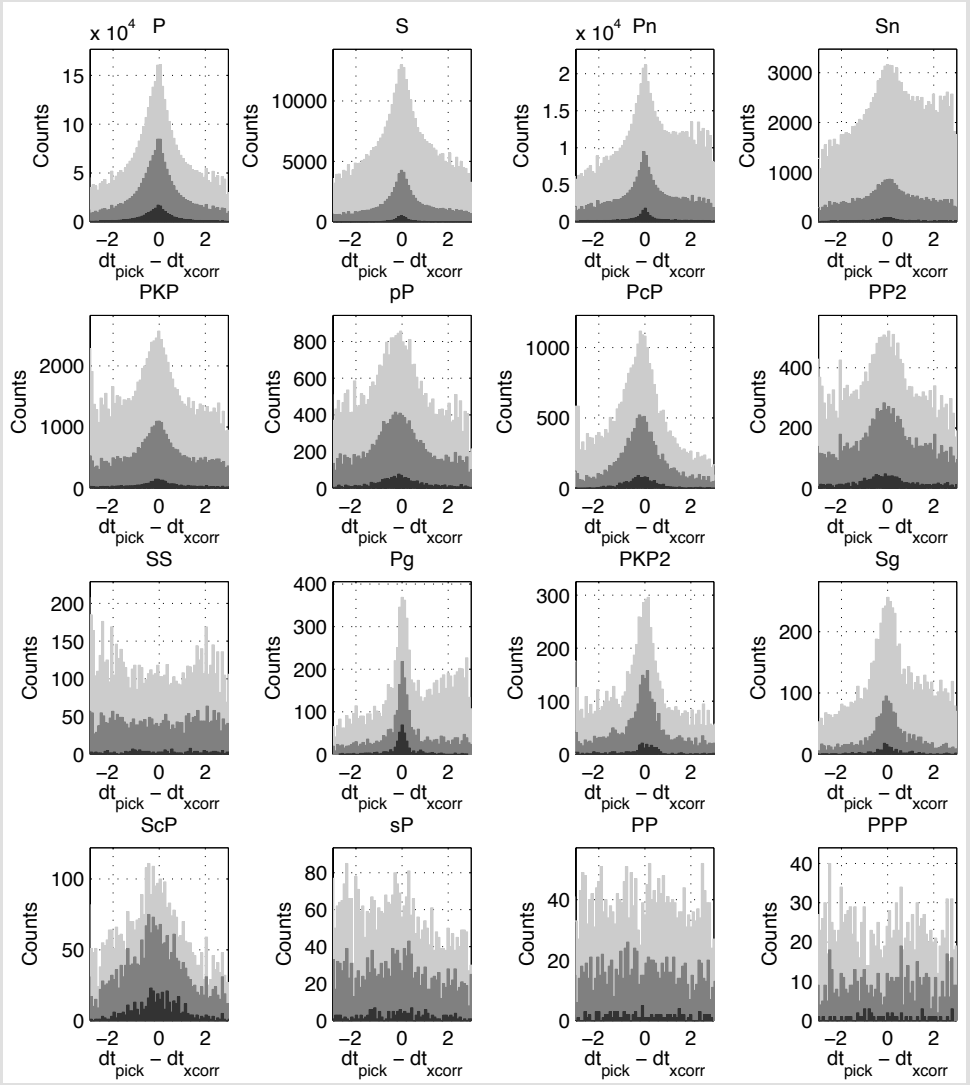
- ~3 million; 13,000 events

Initial analysis with fixed set of parameters!

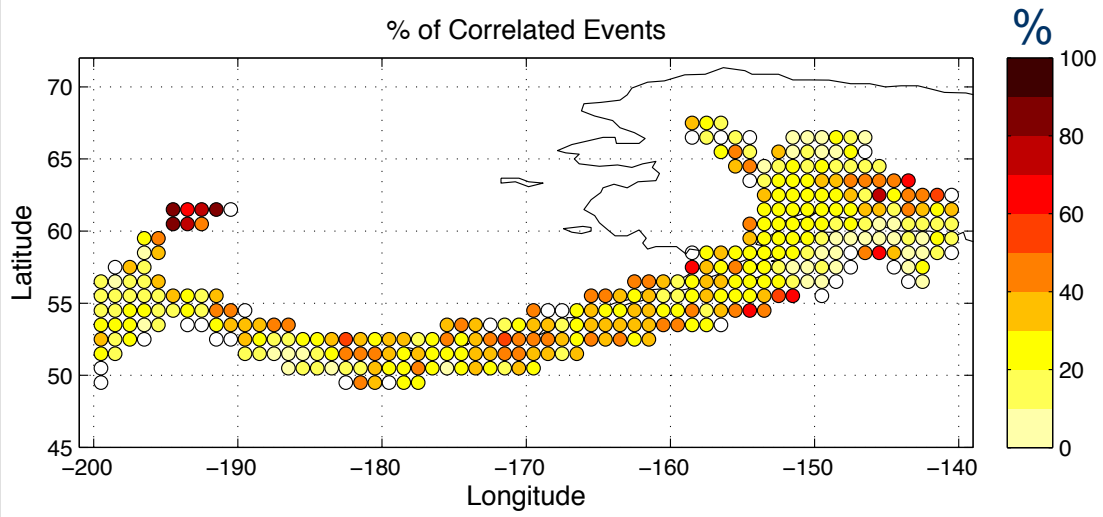
Correlation data for Aleutians

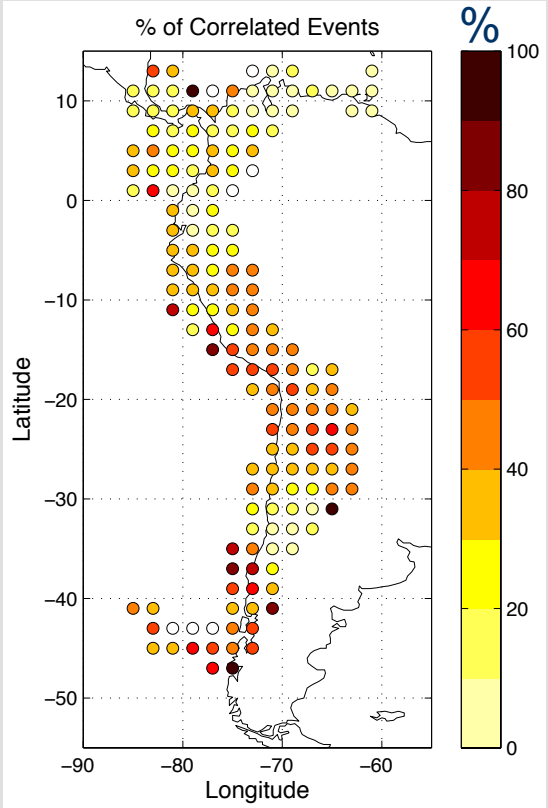


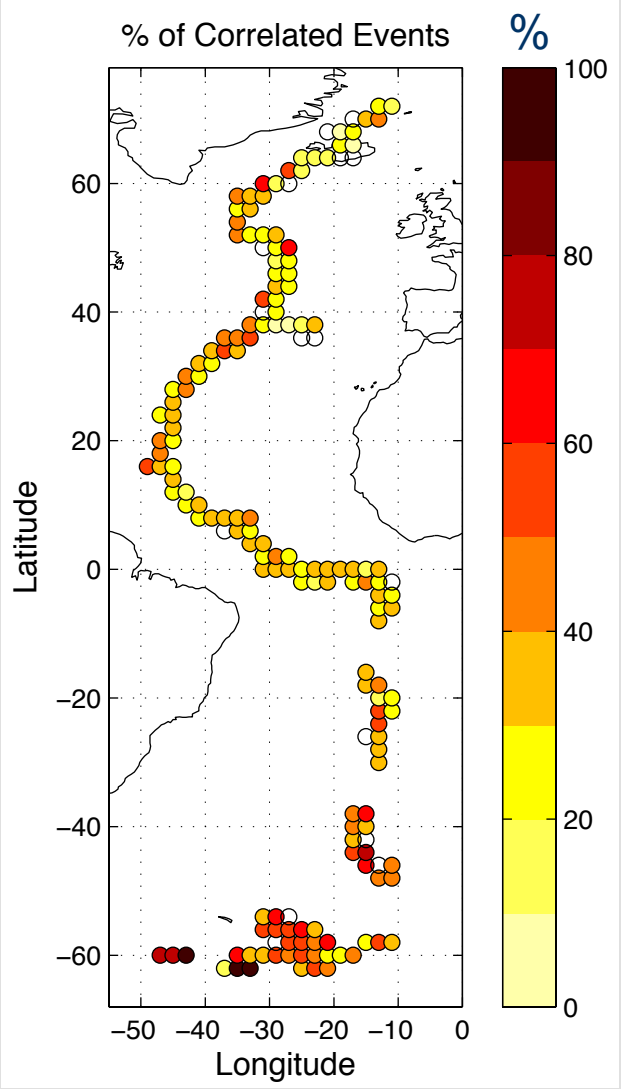
Pick DT - Xcorr DT:



Correlated events







Computational aspects

- Traditional multi-core CPU computing OK for regional-applications such as northern CA (except detection).

- Moving global-scale or high-density DD applications into real-time environments requires better computational solutions:

➔ ***Faster algorithms***
  - PETSc for inversions

➔ ***Faster processors***
  - GPUs for time-series analysis and searches

➔ ***Faster storage solutions***
  - Access to hundreds of millions of files
  - SSD

Summary

- The ISC bulletin continuous to be a tremendously valuable data set for the seismological community and beyond.
- Recent advances in analysis methods and computing performance offer new opportunities for revisiting the 50 years of curated ISC picks.
- High-res relocations sharpen the view of seismicity in most active regions around the world, in particular along subduction zones where event density is high, but also along mid-ocean ridges where existing hypocenters are especially poorly located.
- The new data offers the opportunity to investigate earthquake processes and fault structures along entire plate boundaries at the ~km scale, and provides a common framework that facilitates analysis and comparisons of findings across different plate boundary systems.

Thank You to the ISC and contributing partners!!!