

# *Using ISC data to image Earth's Interior*



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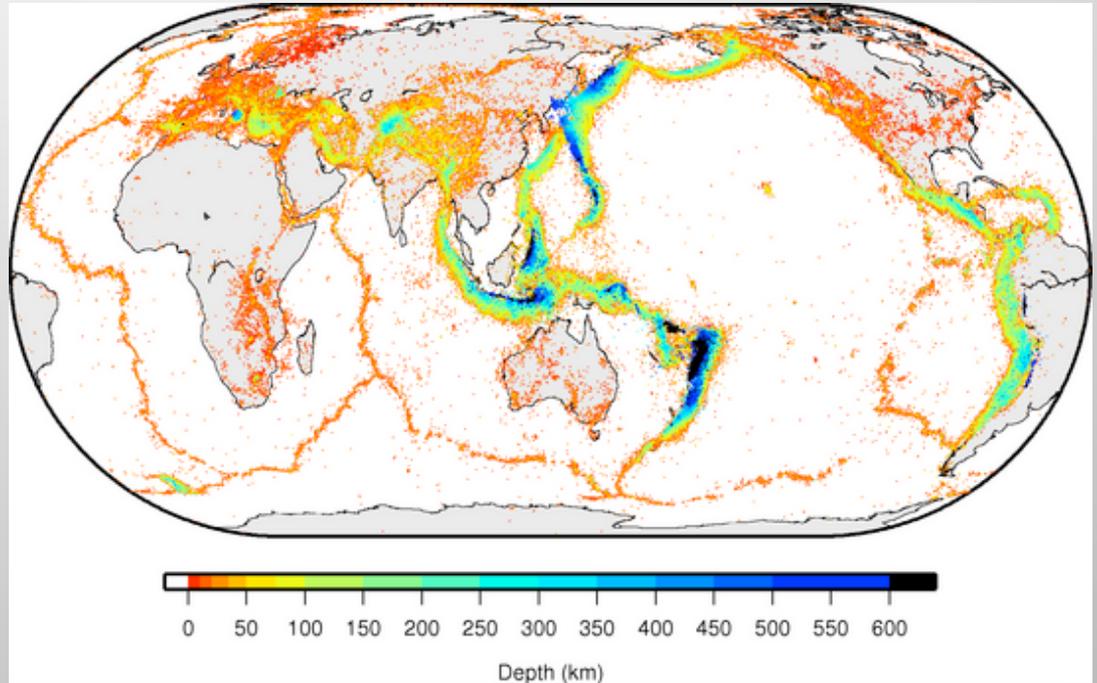
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC



# The ISC collects and distributes the largest set of P-wave travel time arrivals

Data is collected from over 130 agencies worldwide

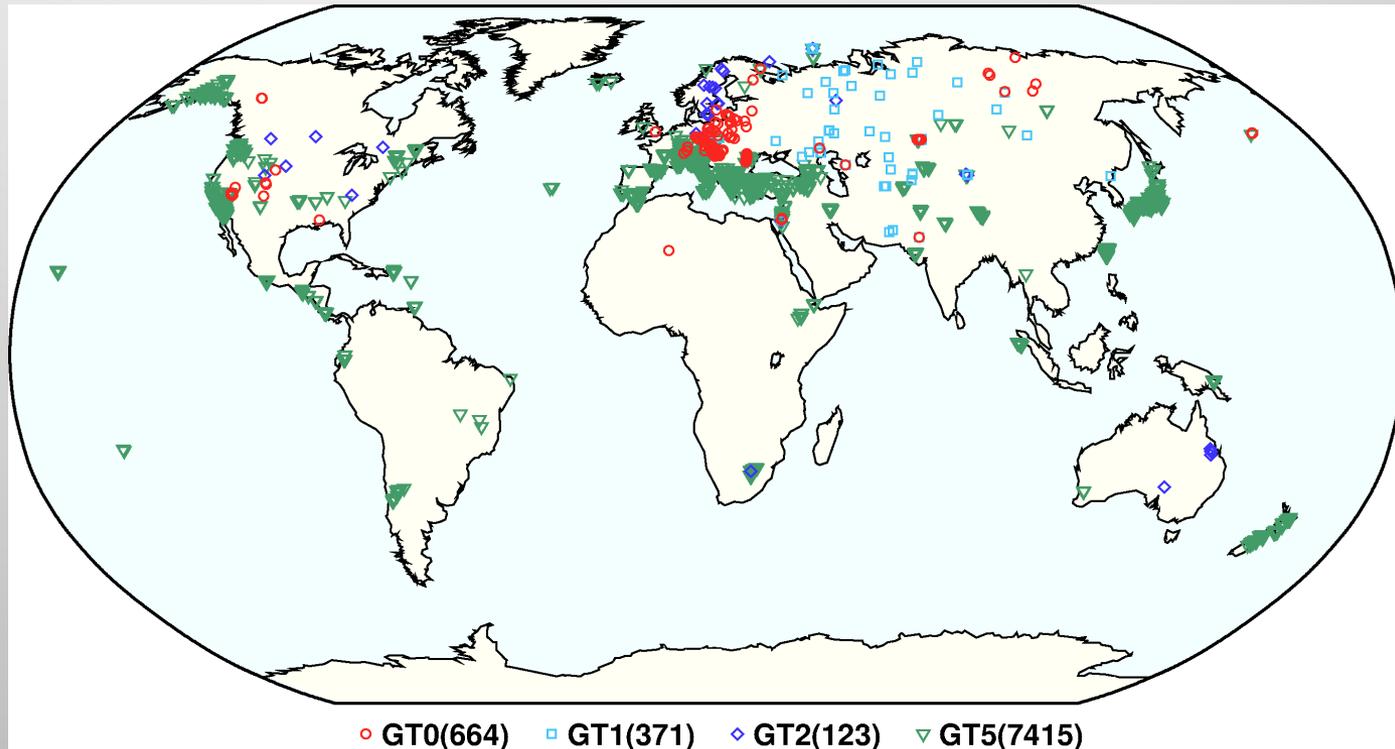
- ISC bulletin constitutes an enormous human effort.
- Measurements are contributed by analysts working at agencies across the globe.
- Contributed arrival-time measurements are associated to seismic events.
- Bulletin locations and arrival data are manually reviewed.
- *The bulletin contains a wealth of information.*



# The ISC Ground True database provides a benchmark for location and travel time studies

Global database of over 7,400 events with well-characterized event locations and associated arrival-time measurements

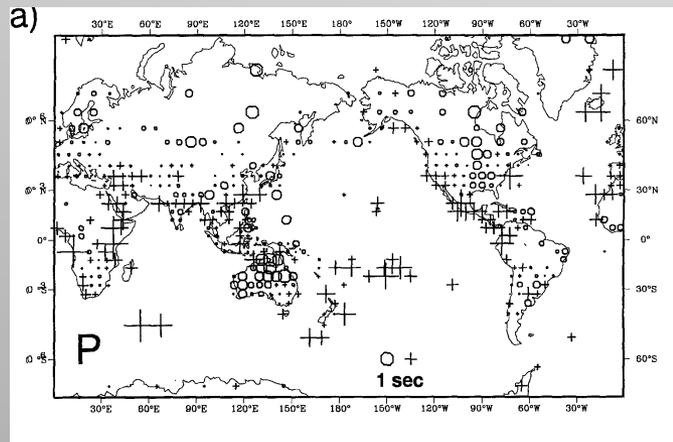
- The ISC GT database consists of contributed information that is vetted by community experts.
- Does not provide sufficient data coverage for tomographic imaging.



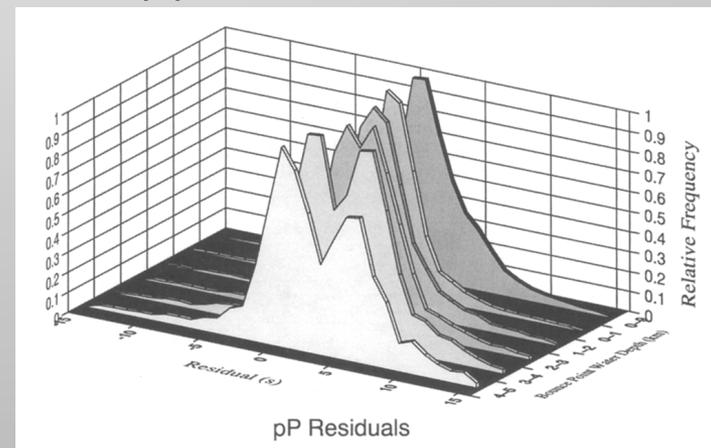
# ISC data must be carefully reworked for use in tomography

- Locations can be biased due to travel time prediction errors.
  - Outlier travel time measurement can also lead to large location errors.
  - Biased locations map to erroneous features in tomographic images.
- ◆ Engdahl, van der Hilst, and Buland (EHB, BSSA 1998) demonstrate that the ISC bulletin can be improved by post processing.
    - ◆ Manual assessment of outliers beyond the efforts of ISC analysts

“Patch” travel-time corrections reduce event location bias



Use of statistical distributions to identify phases



# LLNL developed a semi-automated method to simultaneously relocate events and assess data

Joint Probability function spanning

- Event locations
- Travel times
- Measurement precision
- Phase labels

Statistical model

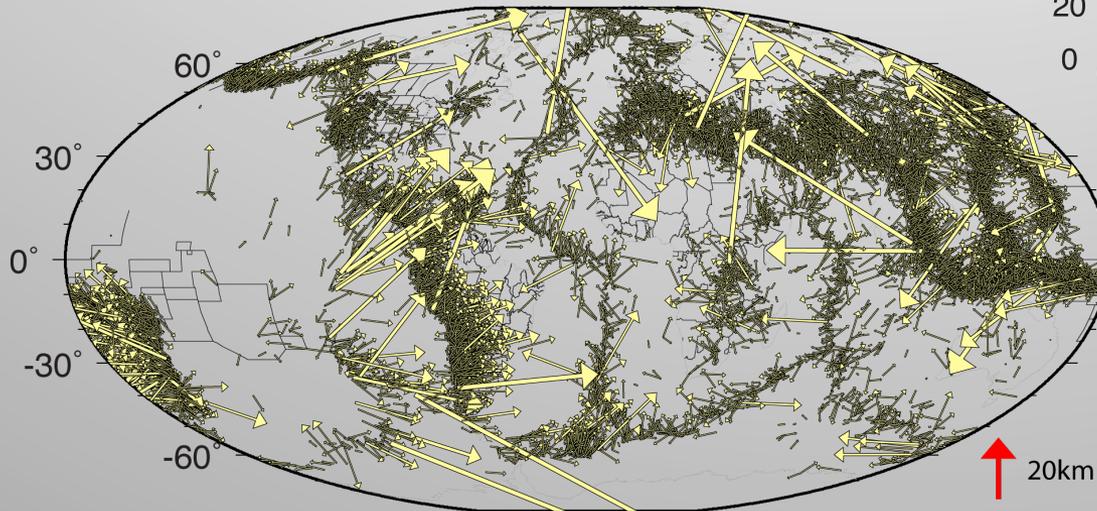
$$p(o, x, T, W, \sigma, V, \tau | a, d, w)$$

Samples drawn using  
Markov-Chain Monte Carlo Method

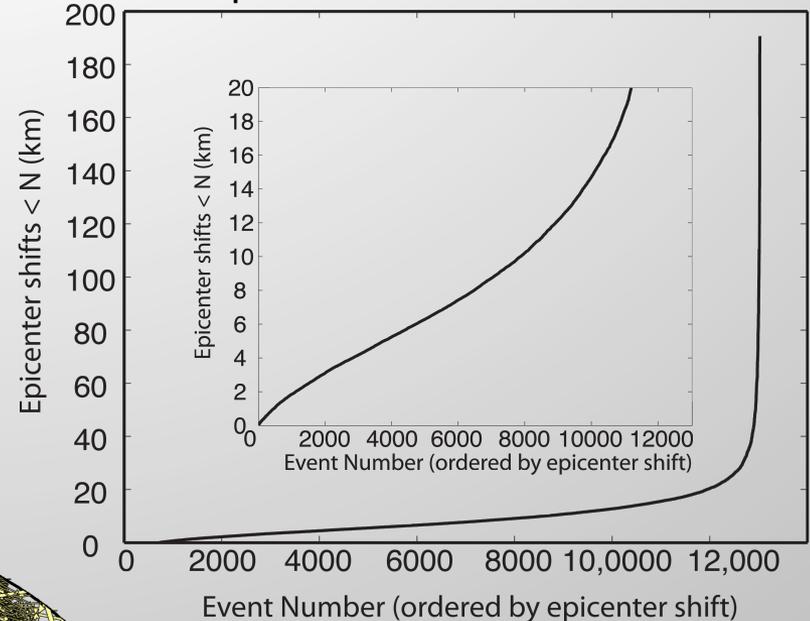
$o$	= origin times
$x$	= locations
$T$	= phase travel times
$W$	= phase labels
$\sigma$	= measurement precisions (pick)
$V$	= measurement precisions (diff)
$\tau$	= travel time corrections
$a$	= arrival times (picks)
$d$	= differential arrival times
$w$	= input phase labels

# Relocation shifts epicenters by 6.8 km (median)

- Epicenter shifts are not random!
  - Epicenter bias is particularly problematic for tomography studies.
- Epicenter shifts are generally less than 10 km
- Large epicenter shifts are most common in subduction zones.



Epicenter shift distribution



Mean depth shifts 5.5 km  
Median origin time shift  
-0.67 seconds

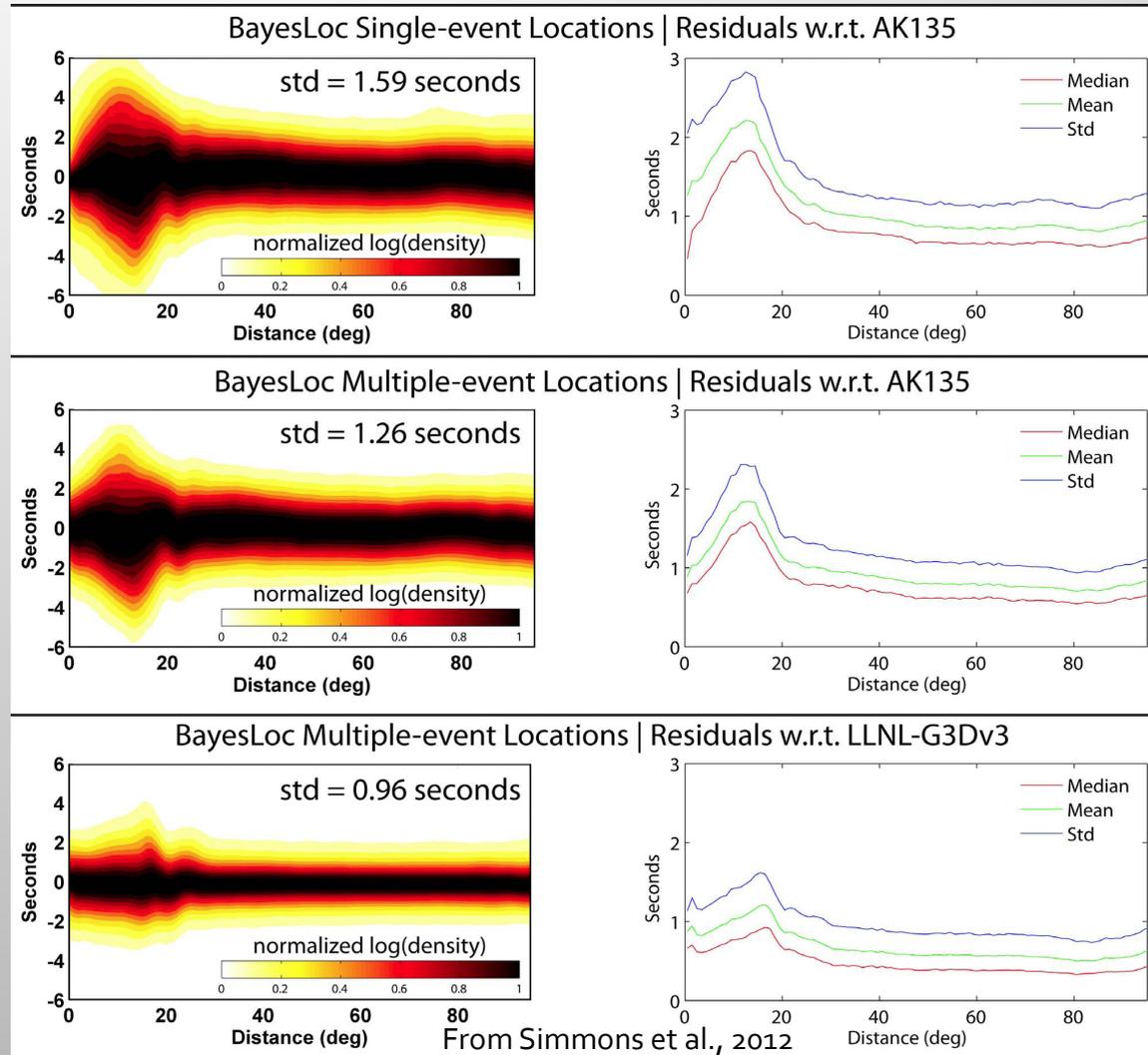
# Bayesloc processing reduces residuals standard deviation by 21% (37% variance reduction)

Bayesloc processing:

- ~3% of data found to be outliers
- Standard deviation is reduced by 21% compared to single-event location
- Large regional-distance residuals remain

Tomography

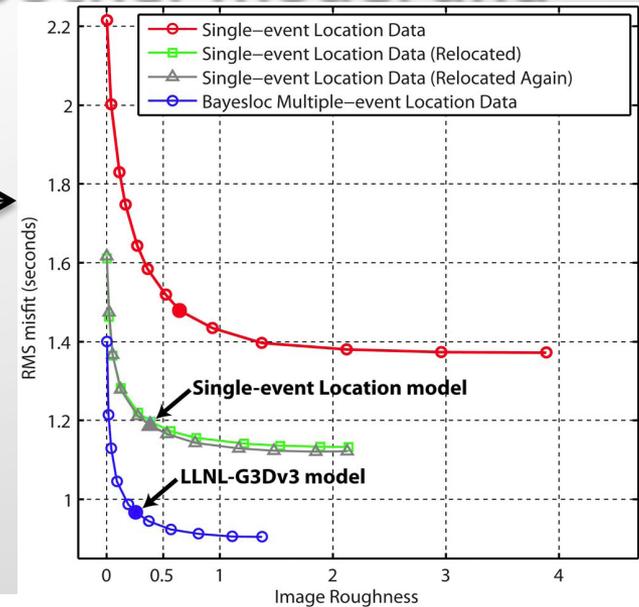
- Further reduces residuals by 24%.
- Large reduction in regional-distance residuals



# Bayesloc processing results in smoother model and improved data fit

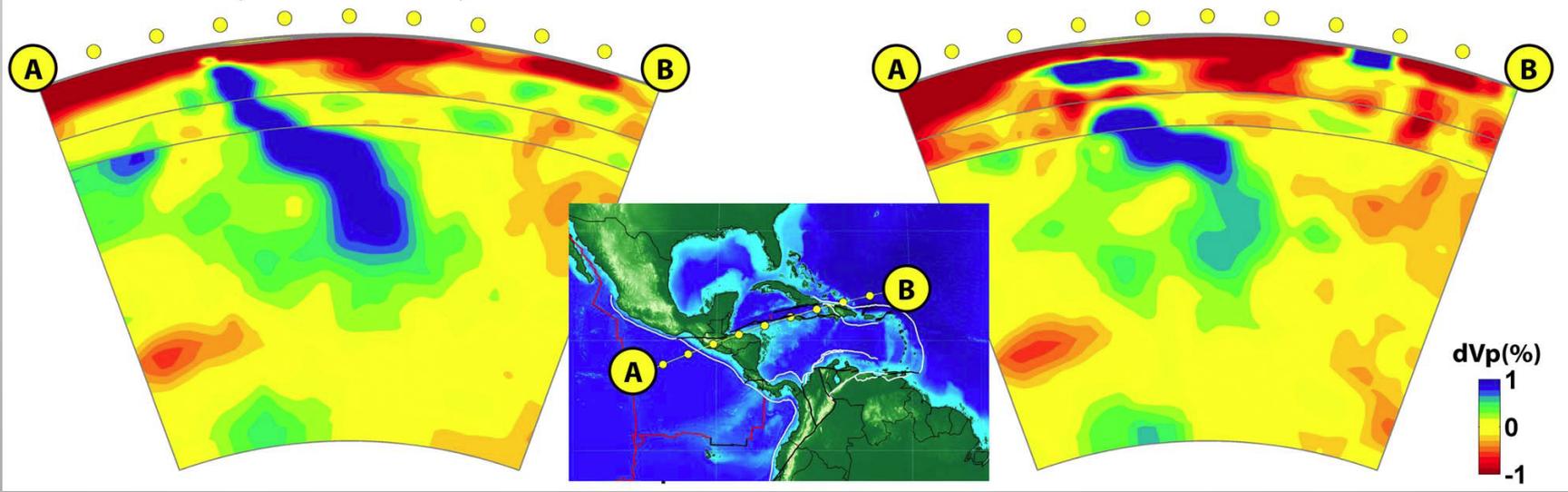
RMS data misfit vs. Tomographic image roughness

Example of differences between tomographic images using data sets for which event locations were determined using multiple-event and single-event (arrival times are identical)



Multiple-Event Location Tomography (LLNL-G3Dv3)

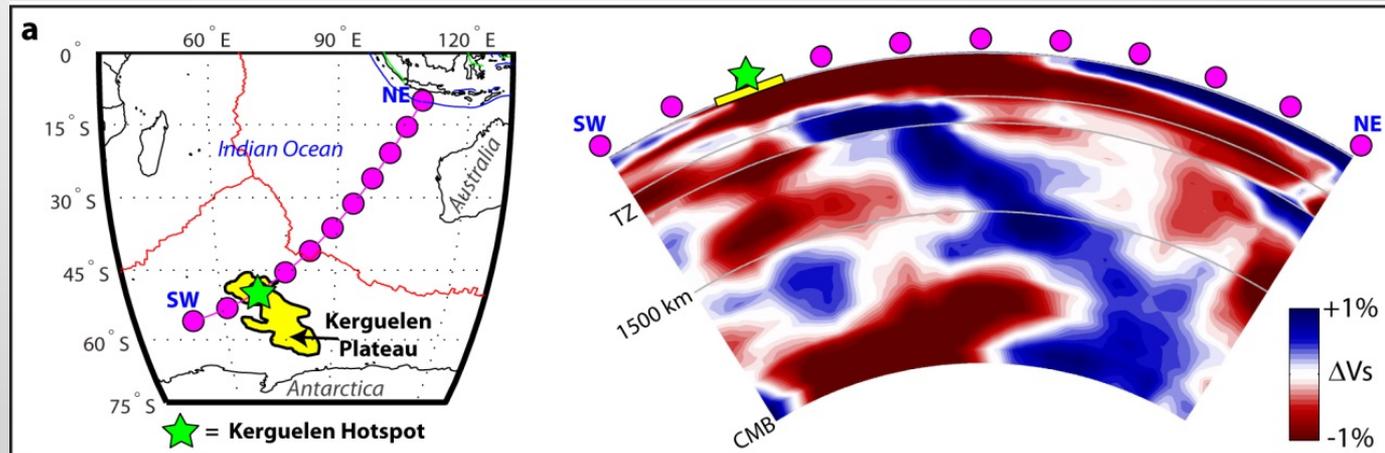
Single-Event Location Tomography



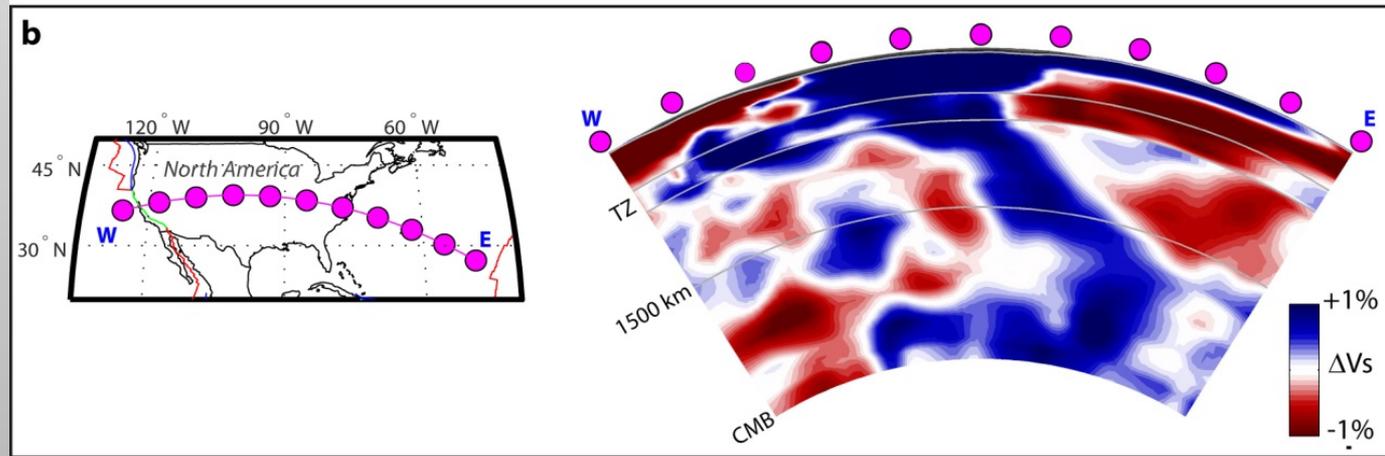
# Identifying new structures?

Tomography based on data set combining Bayesloc-processed P-wave data and S-wave data from U. Texas group

Indian Ocean  
(Ancient slab?)



North America  
(Farallon slab)



# Summary

- The ISC provides a valuable service to the seismic community.
  - Arrivals for some regional networks are only available to the general seismological community via the ISC.
  - Association of arrival-time observations with events is a painstaking process that most researchers are happy to have done at the ISC (modern algorithms may improve efficiency, e.g. NetVISA).
- ISC data is greatly enhanced by post-processing (e.g. EHB, Bayesloc).
  - Tomographic models using are smoother and data fit is improved when ISC events are relocated using Bayesloc.
  - ISC should consider transitioning post-processing procedures into routine processing.