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A Global 3D P-Velocity Model of the Earth's Crust and Mantle For Improved Seismic Event Location

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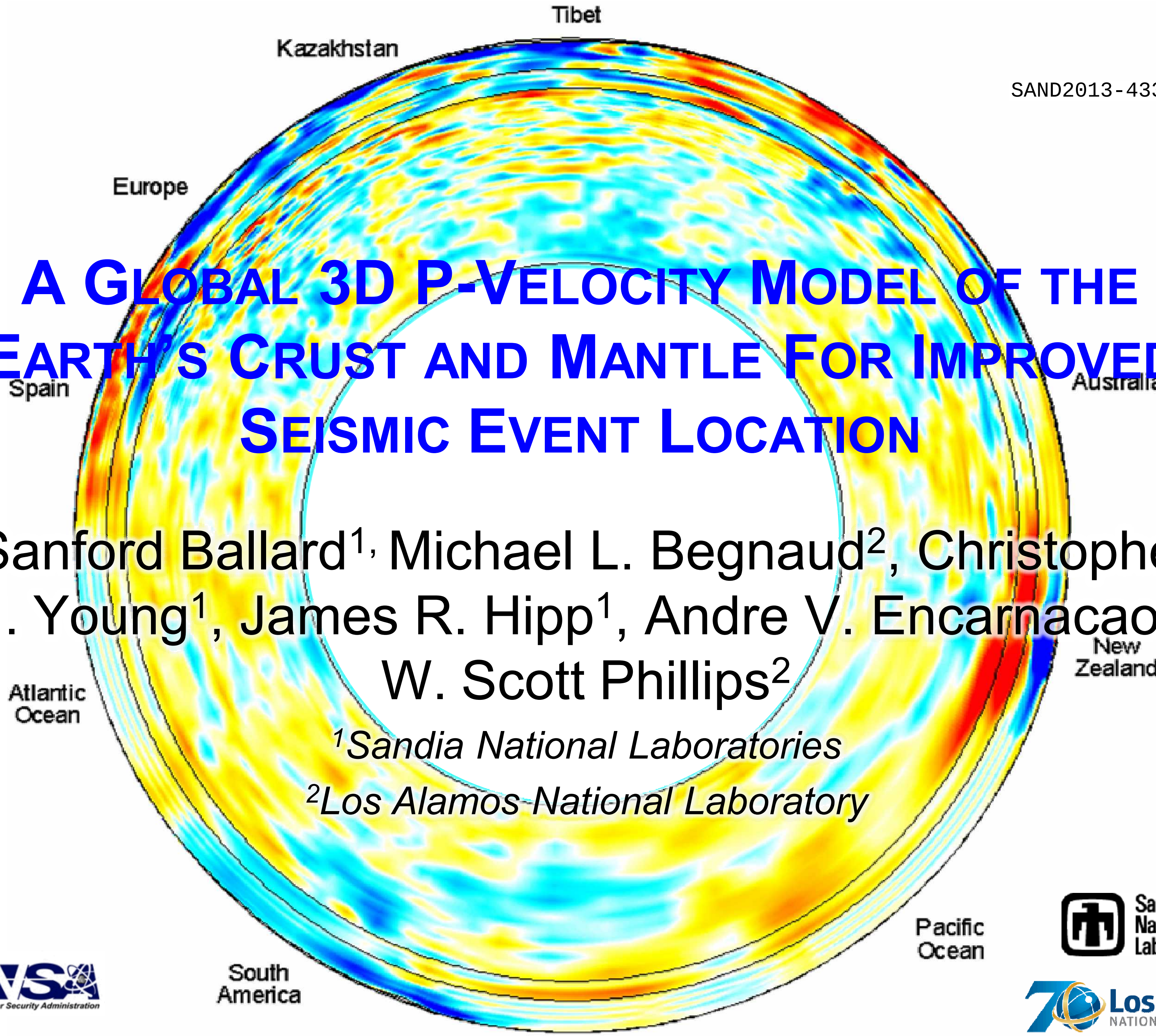
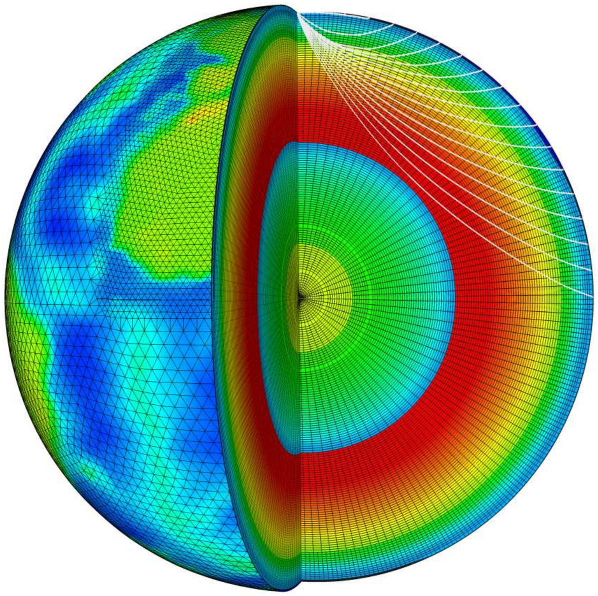


Introduction

- Monitoring the CTBT requires the ability to quickly locate small seismic events anywhere on the Earth with great accuracy and precision.
- This requires the ability to accurately predict the travel time of seismic energy from source to receiver, at local, regional and teleseismic distance ranges.
- The accuracy and precision of travel time prediction is directly related to the fidelity of the Earth models used to make the predictions.
- To date, monitoring agencies have used 1D and 2½D Earth models for travel time prediction, which cannot match the accuracy and precision of full 3D Earth models.
- In this study, we have developed a full 3D velocity model of the Earth's crust and mantle with the single-minded goal of improving the accuracy and precision of seismic event locations.
- Included with our model is software that meets demanding computational requirements.

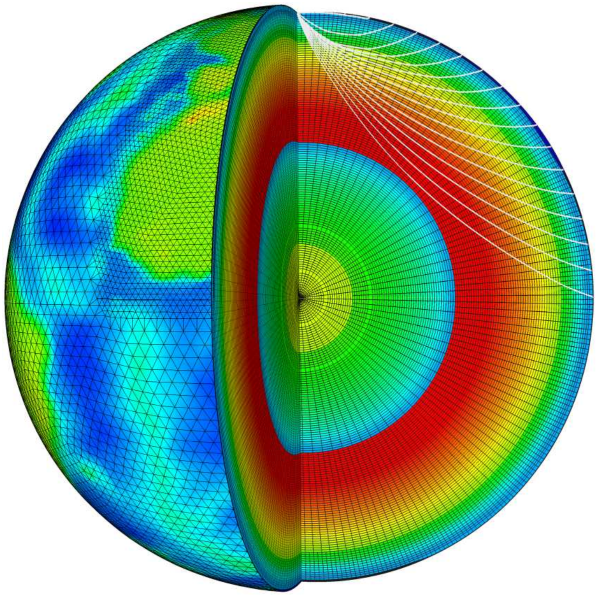
SALSA3D



Outline

- **Tomography**
  - Data
  - Adaptive Gridding
  - Results
- **Validation**
  - Travel time residuals
  - Test Events
- **Model Uncertainty**
  - Model Covariance Matrix

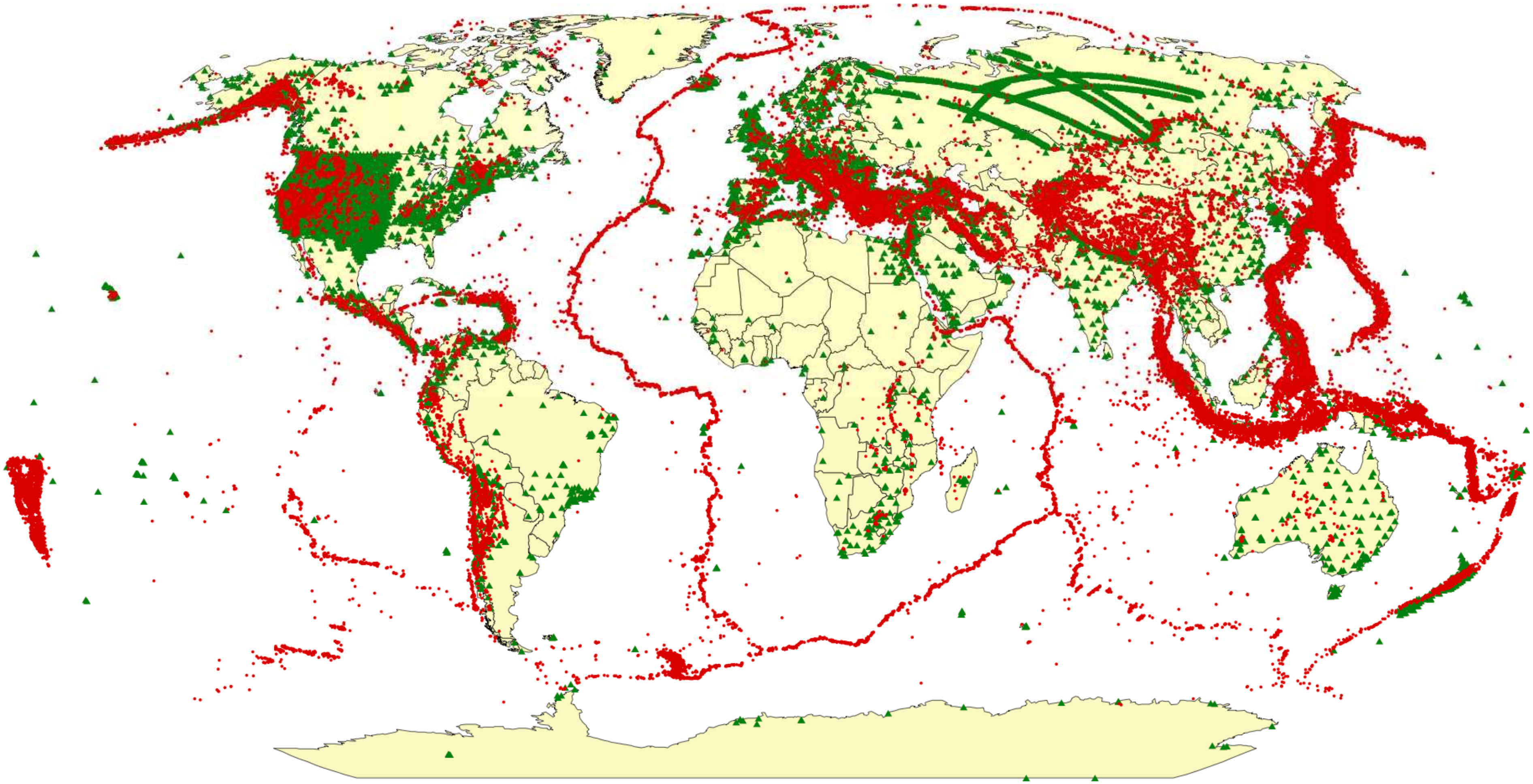
SALSA3D



Data

Ground Truth (GT) 25 km or better *(Bondár et al., 2004)*

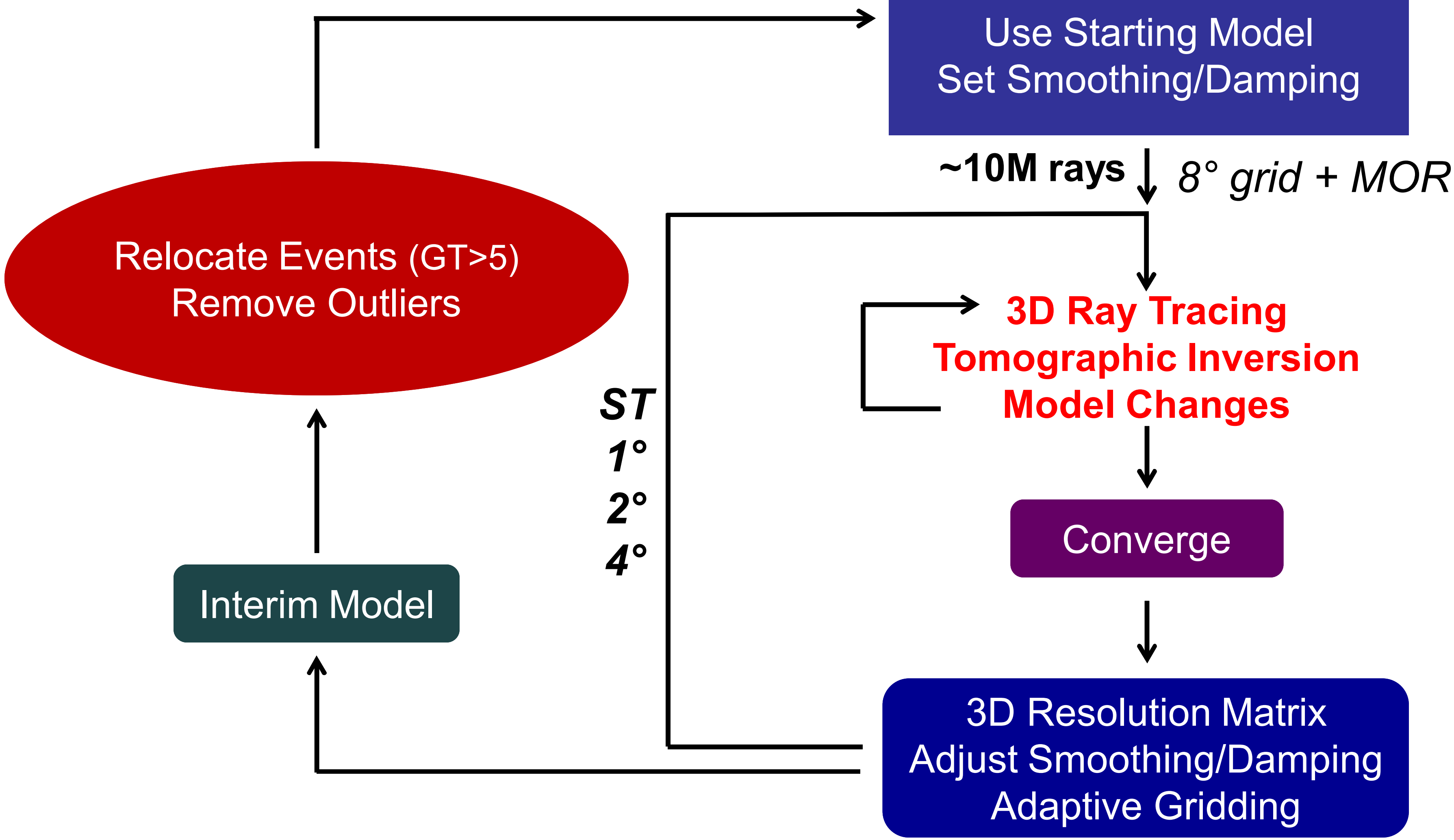
122K events   13K stations   10M ray paths



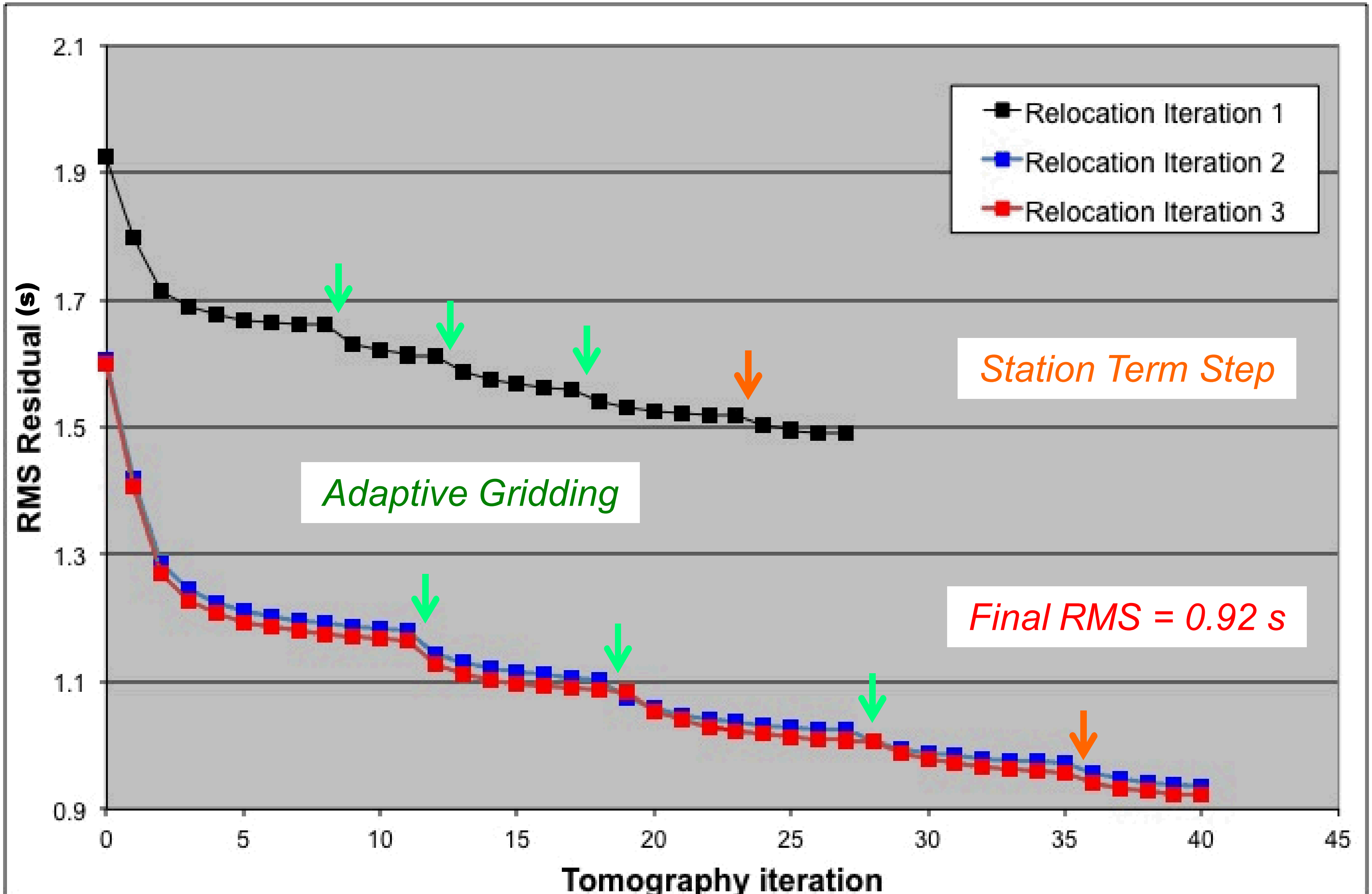
Tomographic Procedure

LSQR algorithm of Paige and Saunders (1982)

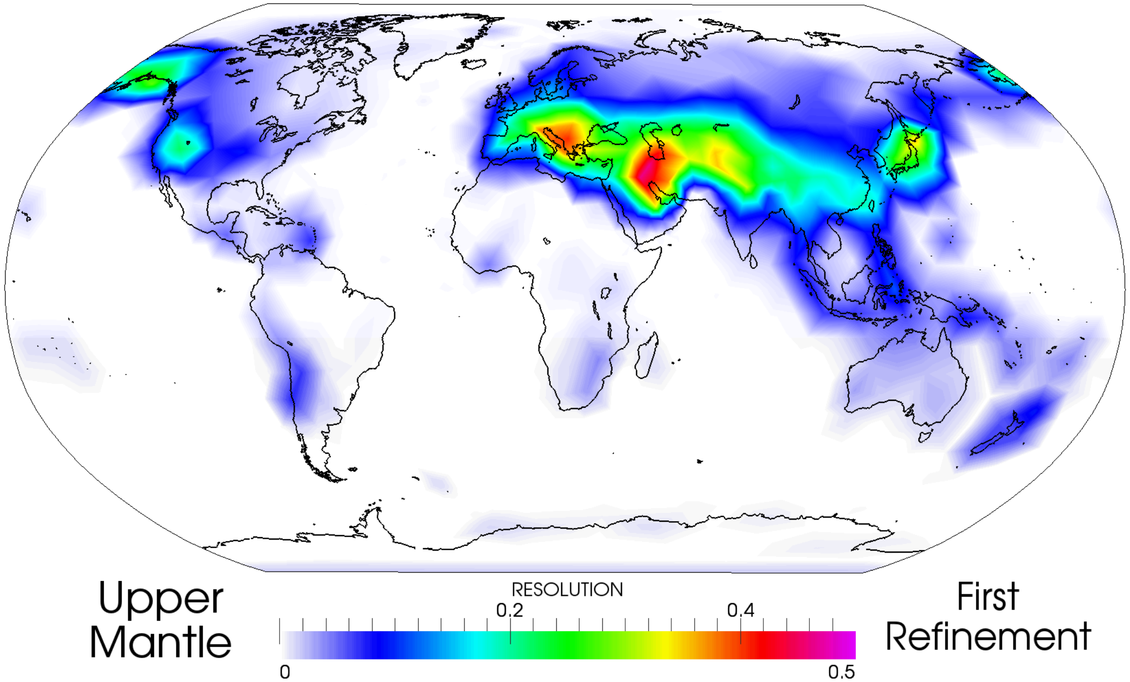
Model Slowness Uncertainties added (smoothing, damping) to allow proper calculation of ***full 3D covariance matrix for travel time uncertainty****.*

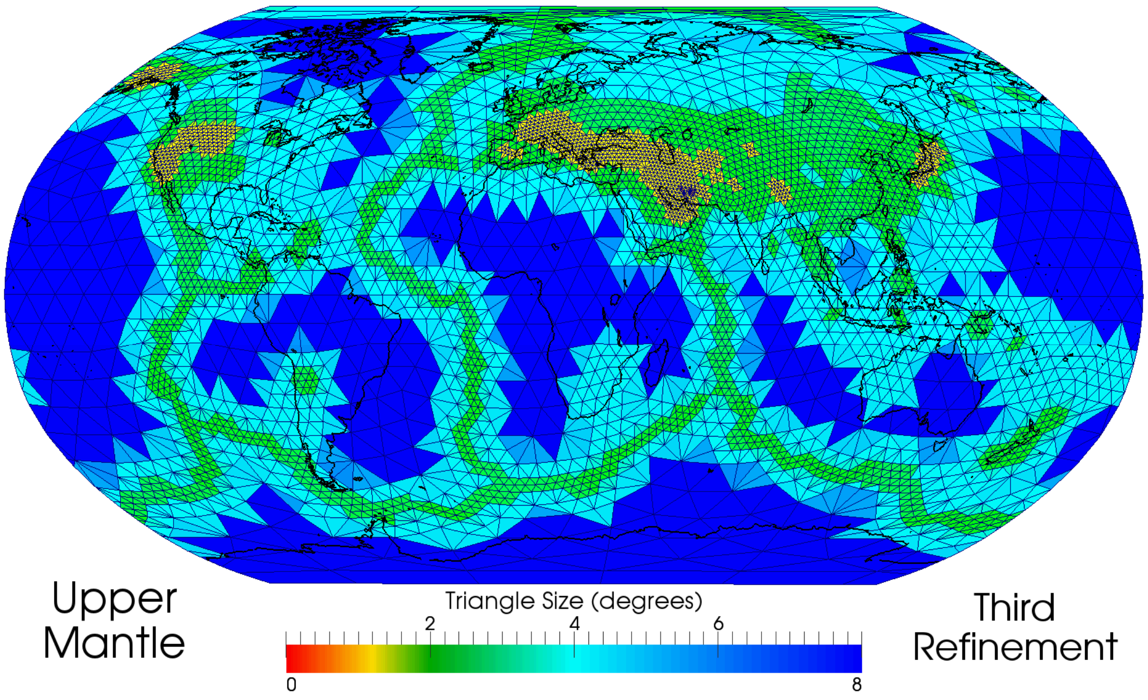


Tomography Iterations and RMS



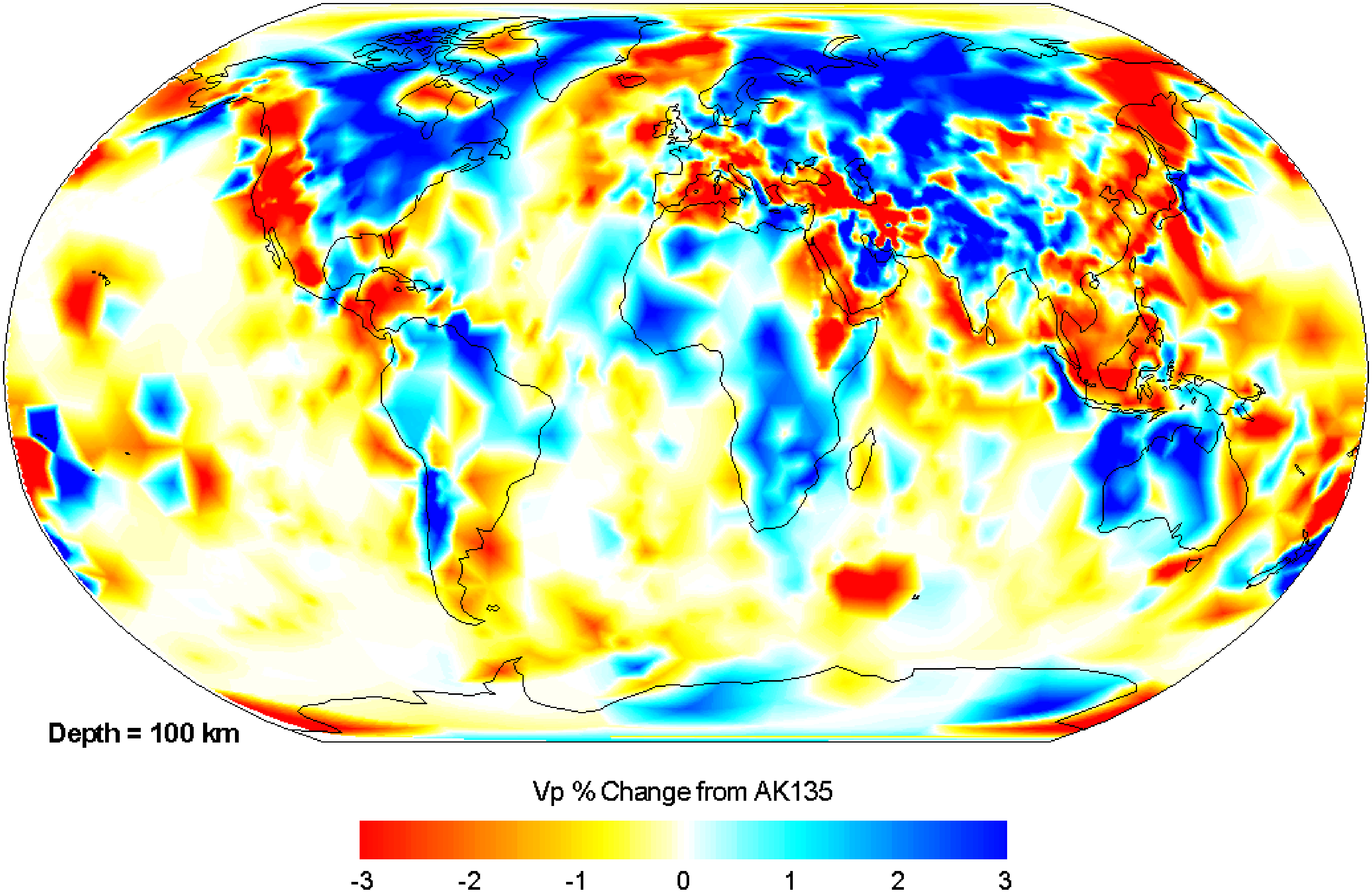
Variable Resolution Grids



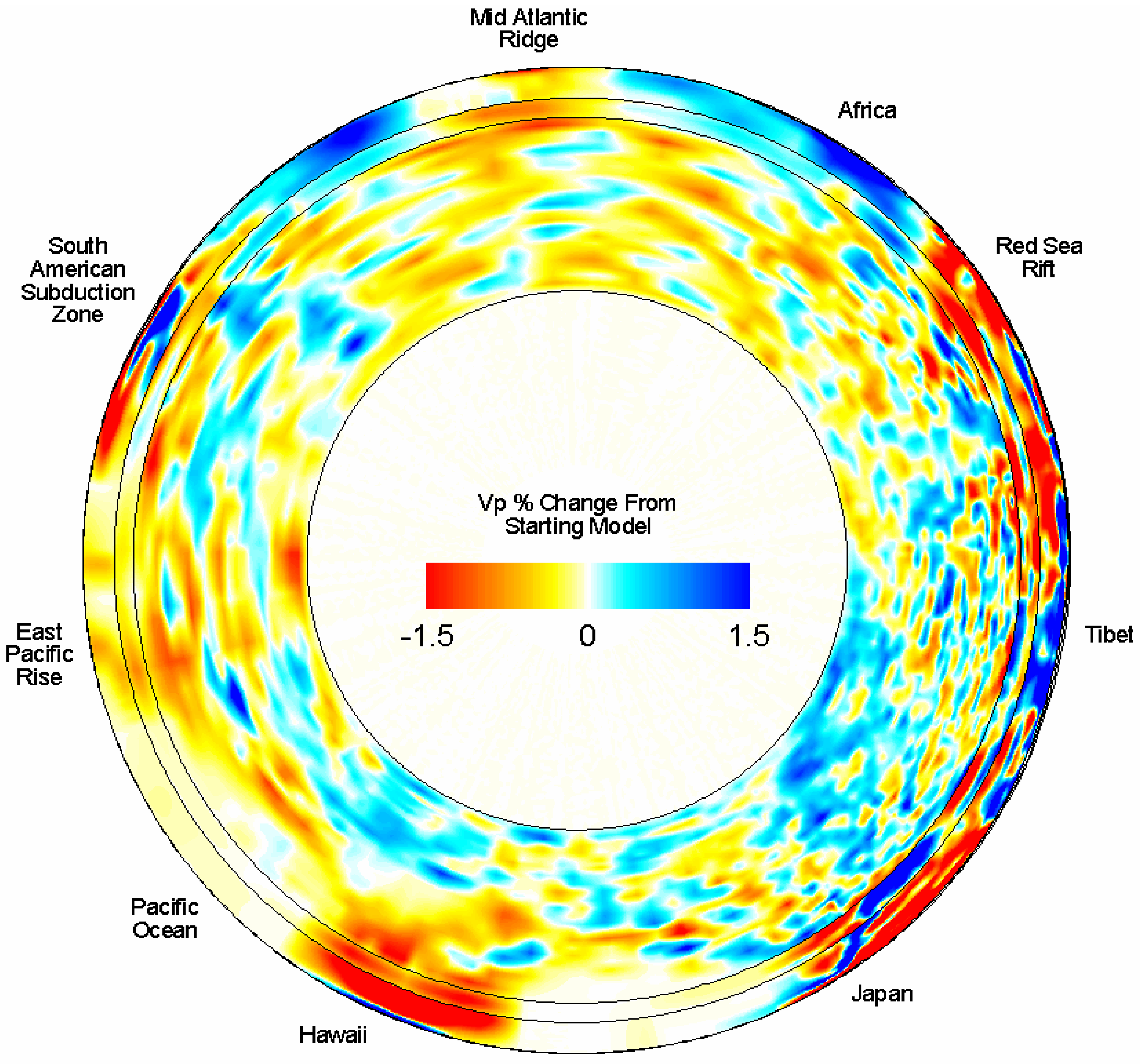


Grids are constructed and managed using GeoTess open source software www.sandia.gov/geotess

SALSA3D

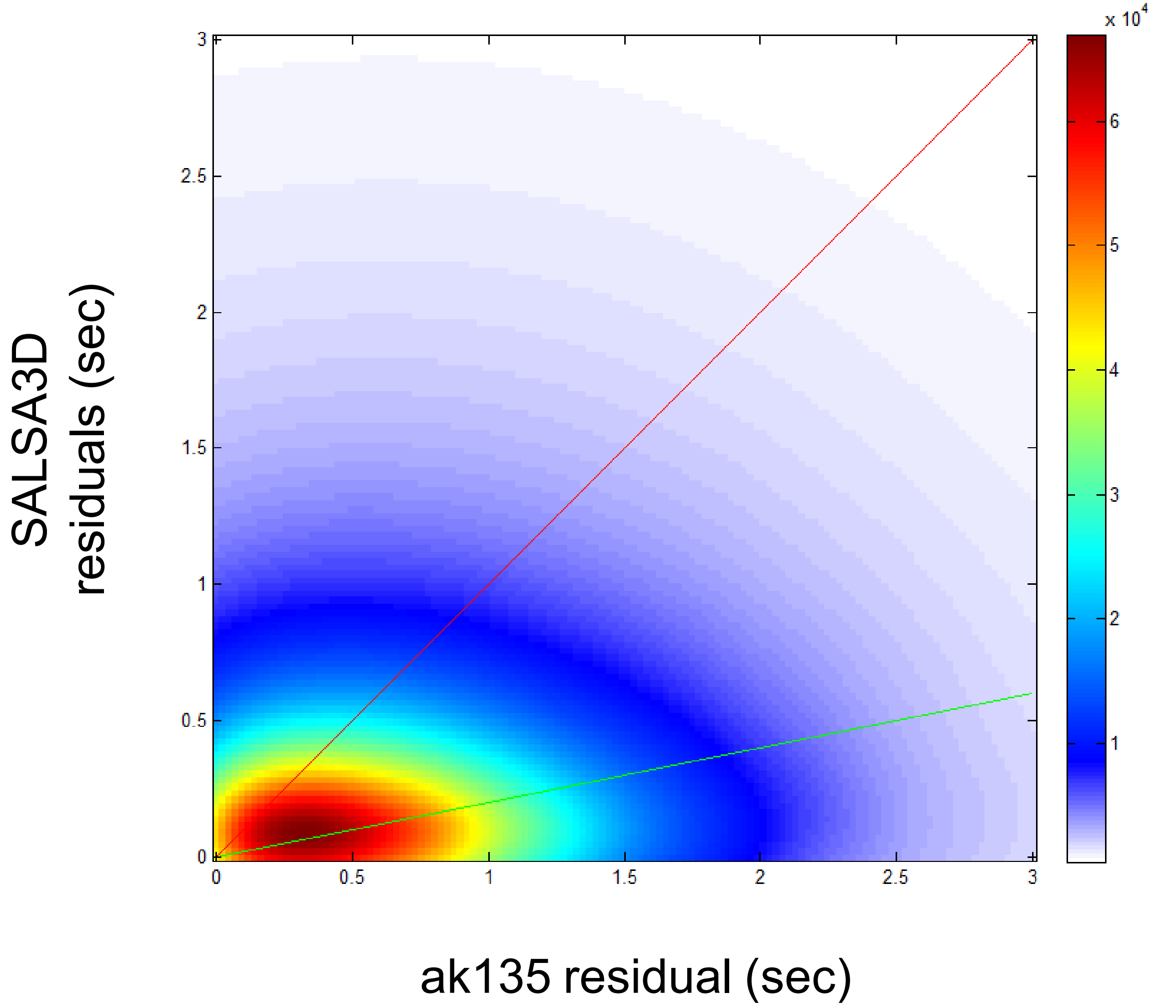


SALSA3D



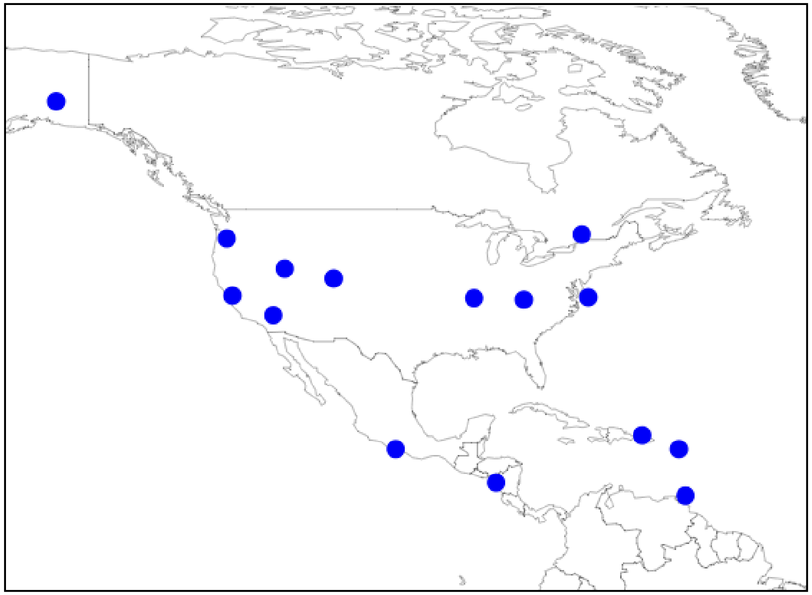
Mid Atlantic Ridge
Africa
Red Sea Rift
Tibet
Japan
Hawaii
Pacific Ocean
East Pacific Rise
South American Subduction Zone
Vp % Change From Starting Model
-1.5
0
1.5

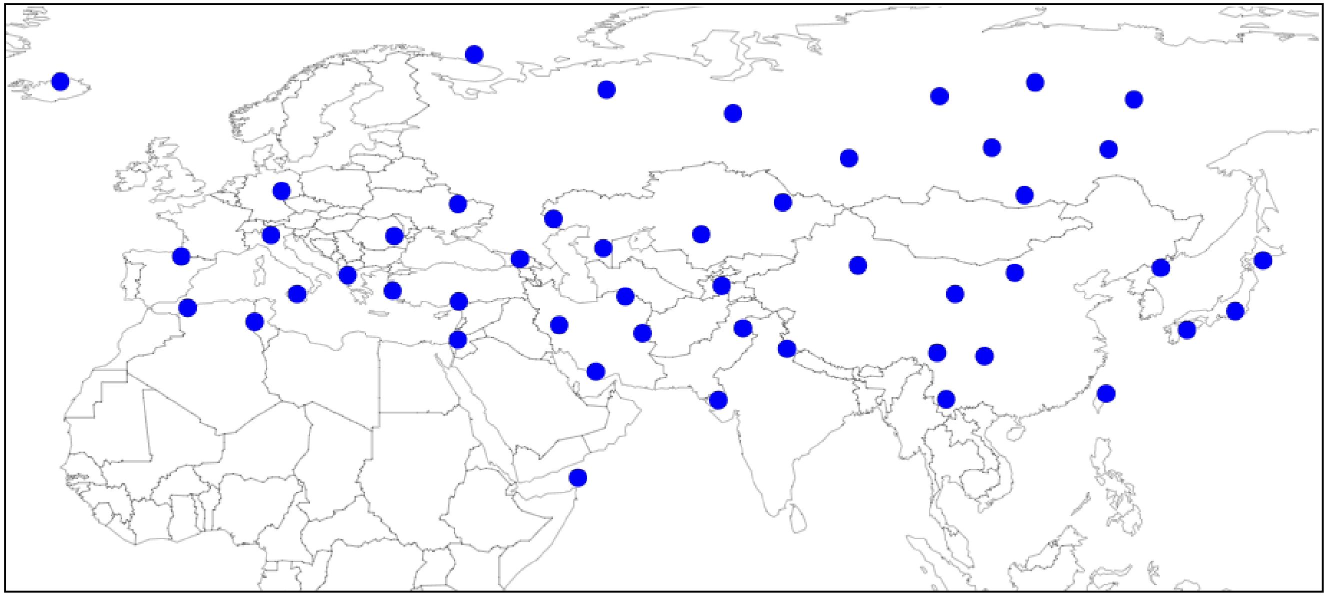
Residual Reduction



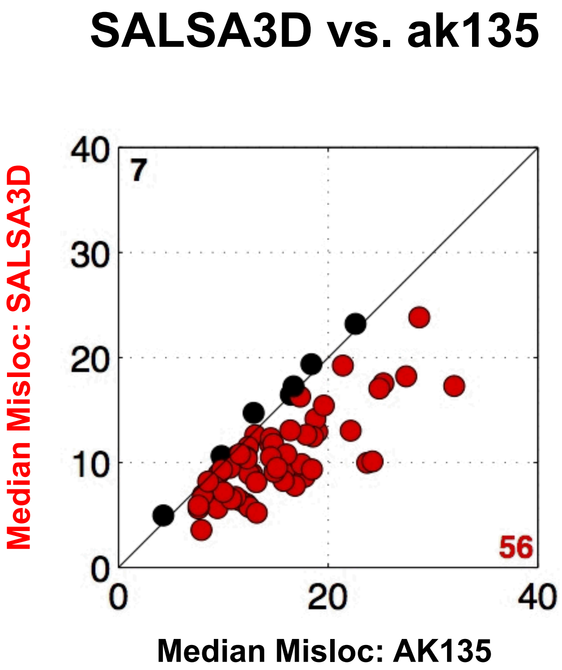
Validation and Model Comparison

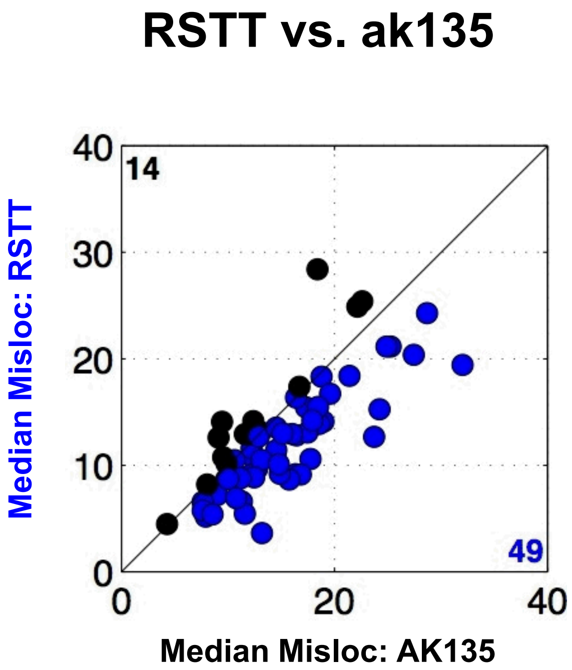
- ak135
- RSTT / ak135
- SALSA3D

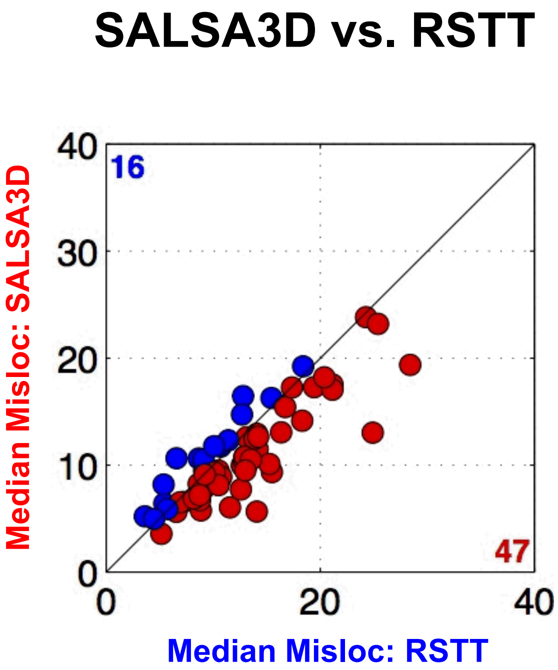




Event Mislocation Comparisons



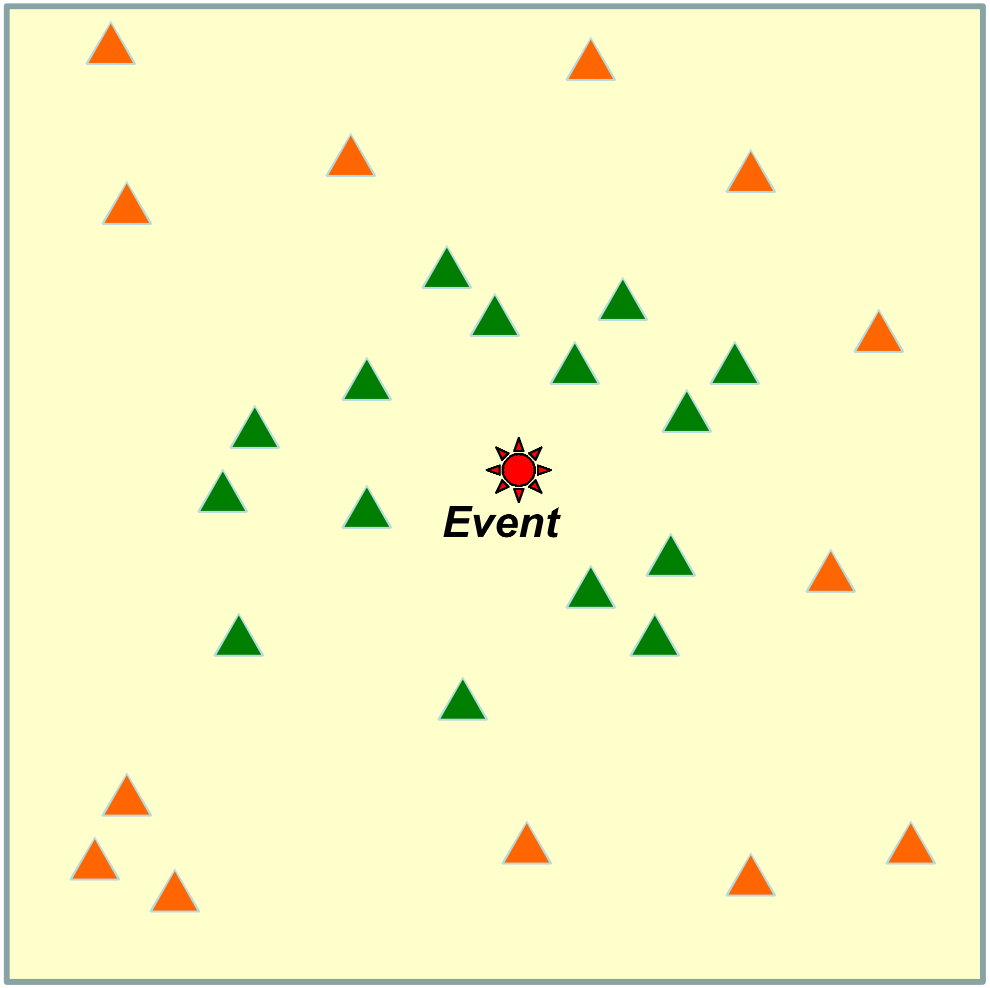


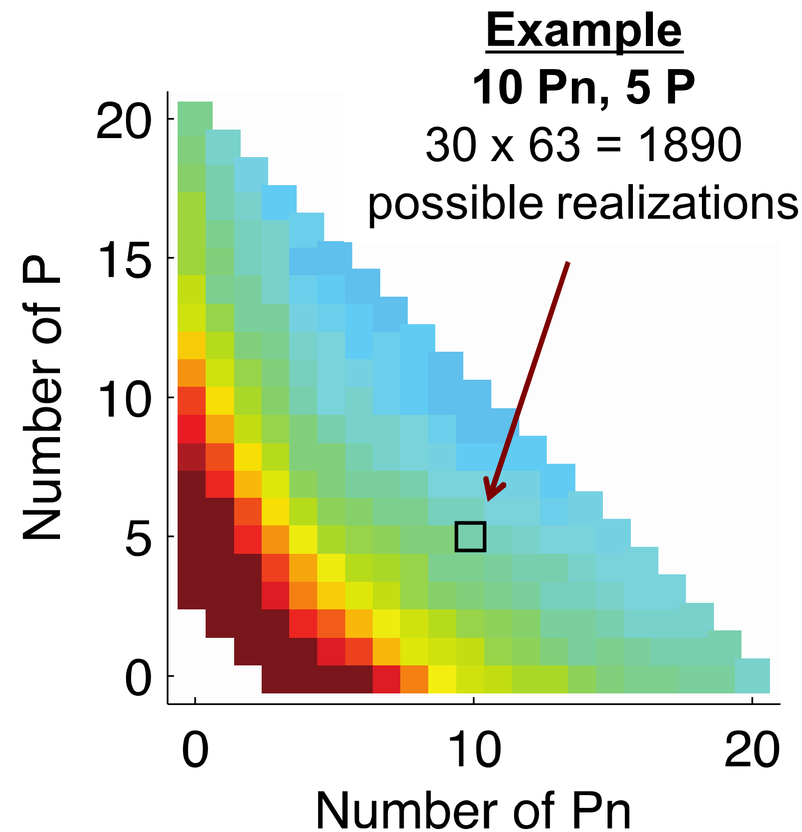


Generation of Random Realizations

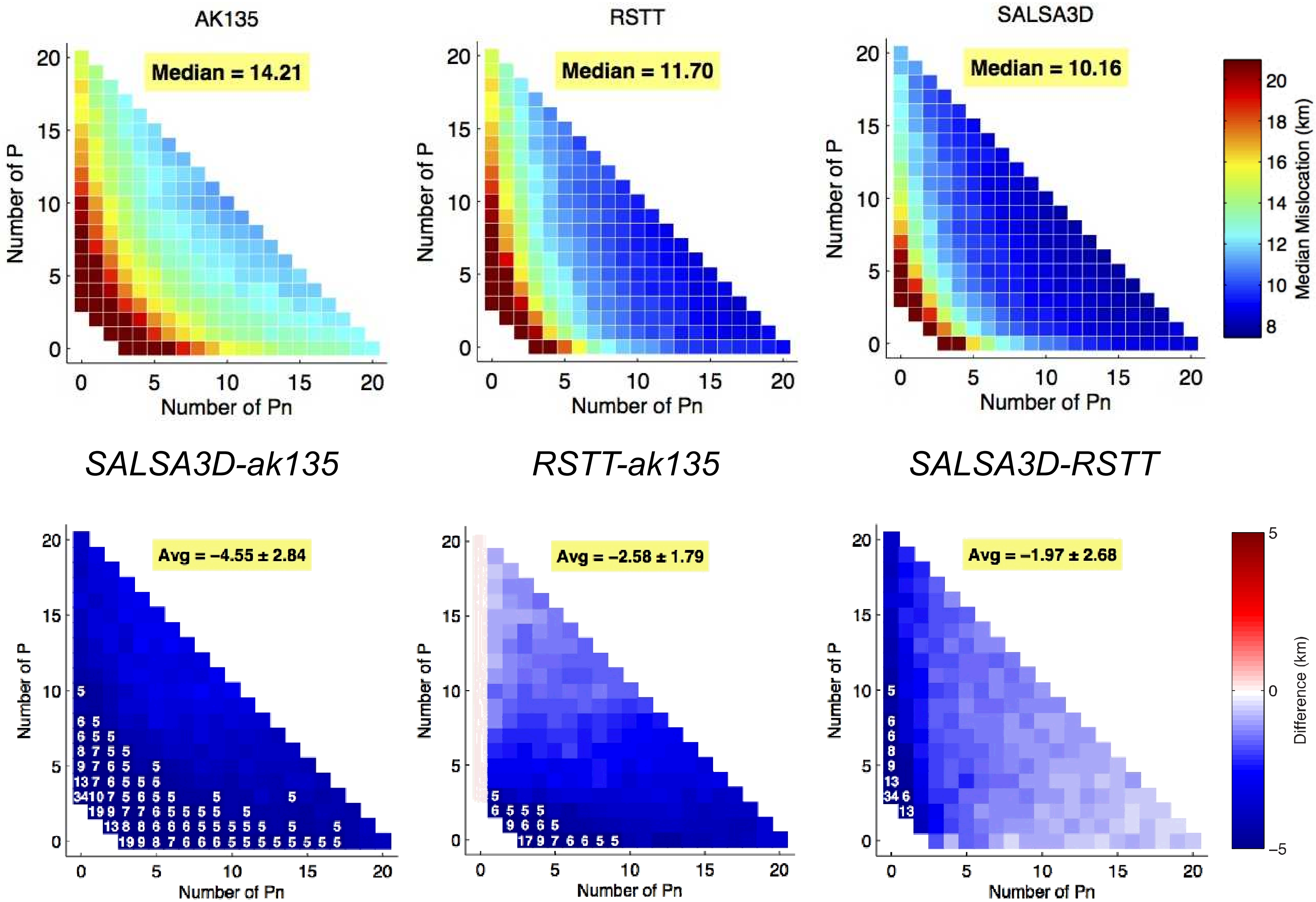
- **For each validation event, randomly select many subsets of the available P and Pn arrivals**

Stations: ***Regional (Pn)*** ***Teleseismic (P)***

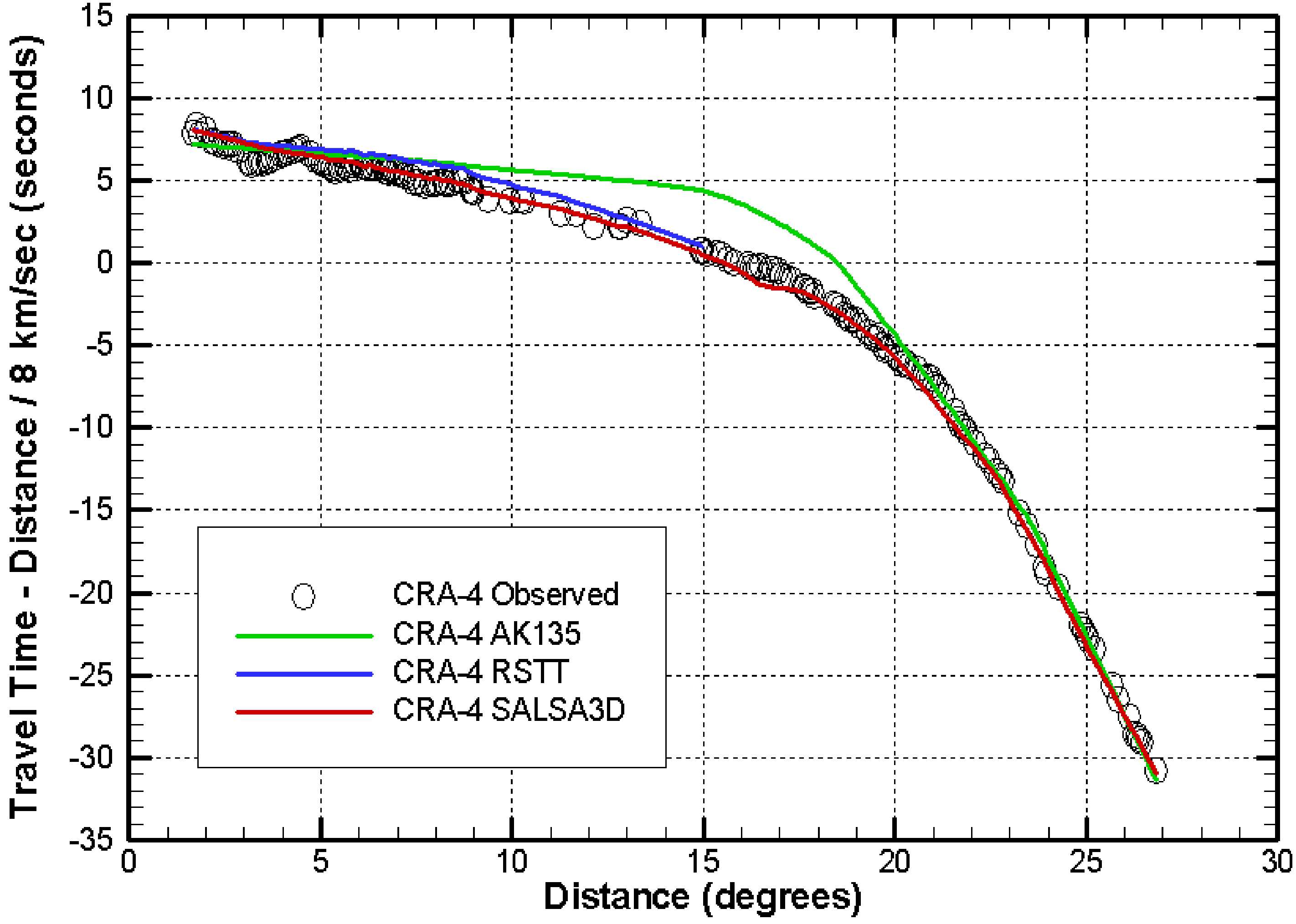




Mislocation Grids



DSS Lines Across the Siberian Platform



Uncertainty

Basic Tomography Equation

$$\begin{bmatrix} C_{d_0}^{-1/2} & 0 \\ 0 & C_{s_0}^{-1/2} \end{bmatrix} \begin{bmatrix} A \\ \alpha L \end{bmatrix} \Delta s = \begin{bmatrix} C_{d_0}^{-1/2} & 0 \\ 0 & C_{s_0}^{-1/2} \end{bmatrix} \begin{bmatrix} \Delta d \\ 0 \end{bmatrix}$$

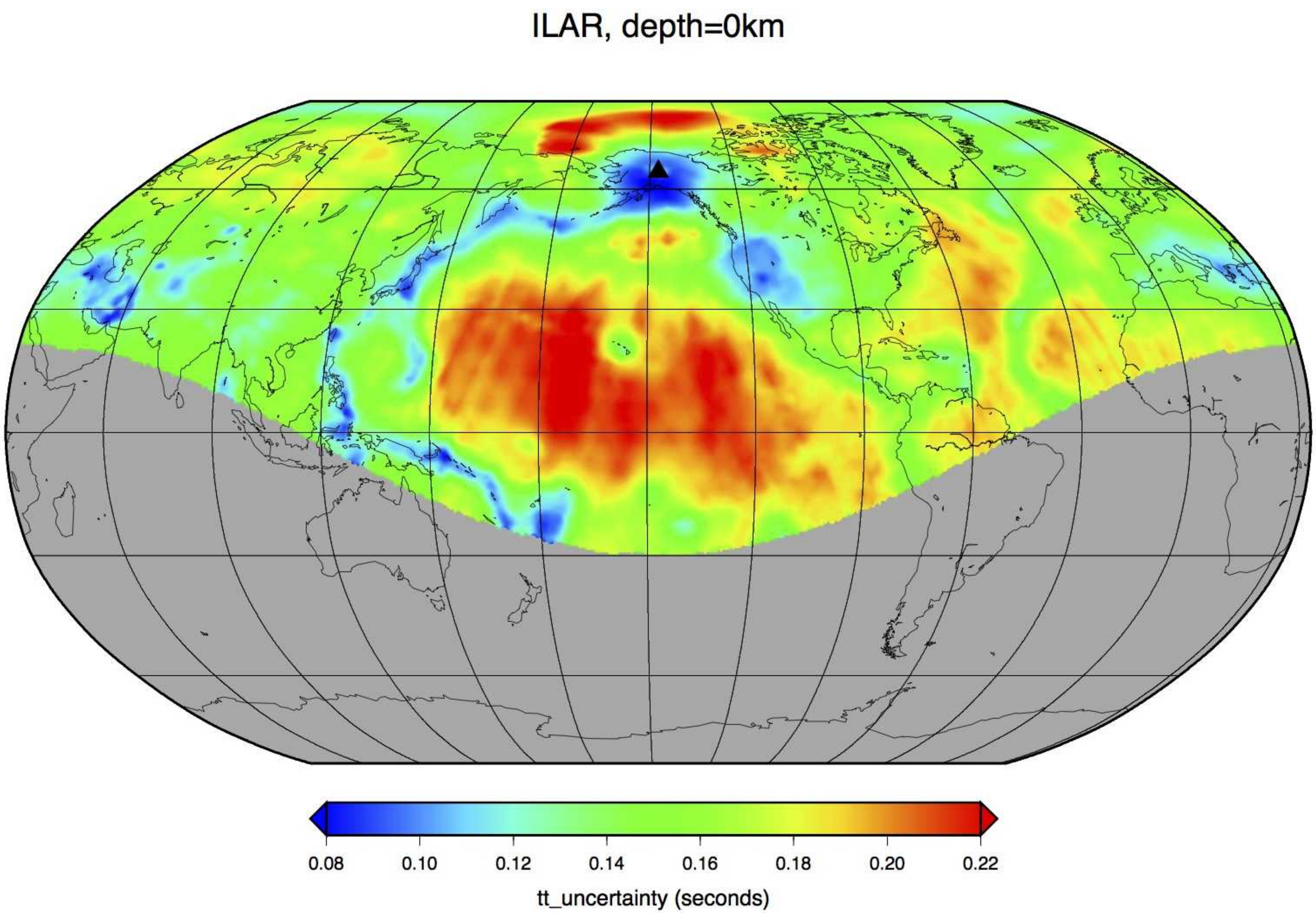
Uncertainty of the P Wave Velocity in the Mantle

$$C_{m_w} = \left[C_{s_0}^{-1} + A^T C_{d_0}^{-1} A \right]^{-1}$$

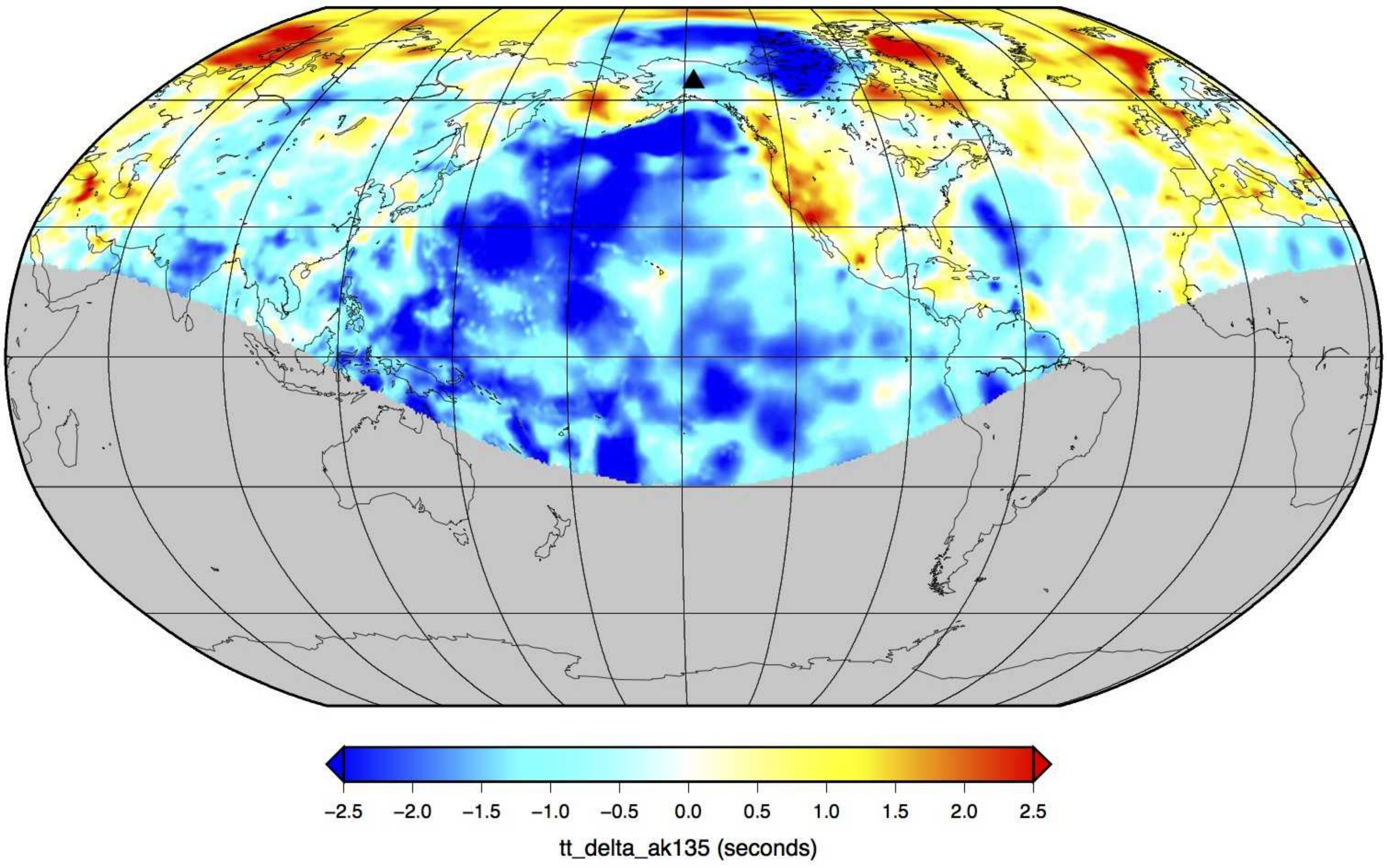
Travel Time Uncertainty for a Singe Ray Through the Earth

$$\sigma_{tt}^2 = \iint_{path} C_M \, dx$$

Travel Time Prediction Uncertainty



Travel Time Δak135



Travel time and uncertainty stored in 3D lookup tables using GeoTess software (www.sandia.gov/geotess)

Conclusions

- SALSA3D is a 3D multi-resolution model of the compressional wave speed in the Earth constructed with the goal of improving the accuracy and precision of seismic event location.
- SALSA3D successfully images many tectonic features within the Earth.
- Unambiguous improvement in travel-time prediction and event location compared to ak135 and RSTT/ak135, especially for events observed by a network of stations that is small or has poor geometry.
- Path dependent travel time prediction uncertainties are calculated using the full model covariance matrix computed during tomography.
- Station-phase specific travel time predictions and uncertainties are pre-calculated for a network and stored in 3D lookup tables. Retrieval is very fast and accurate using open source GeoTess software (www.sandia.gov/geotess).