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Title: Seismic and Infrasound Location

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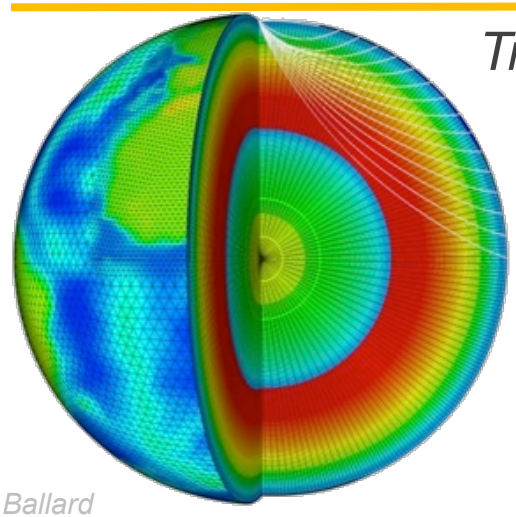
Seismic and Infrasound Location

Stephen Arrowsmith & Michael Begnaud

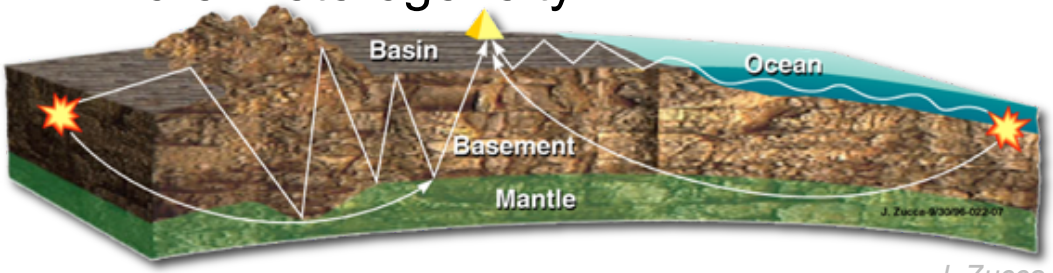
Signal Propagation Through the Earth/Atmosphere Varies at Different Scales



S. Ballard

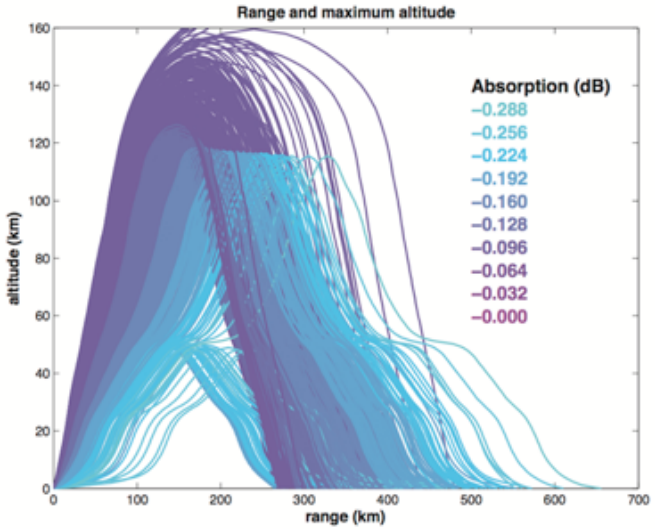
Travel Times, Amplitudes, Waveforms

- Teleseismic Distances (> ~15-20 deg)
  - Rays mostly travel through the mantle
  - "Less" heterogeneity
- Regional Distances (< ~15-20 deg)
  - Rays travel through the crust and upper mantle
  - "More" heterogeneity



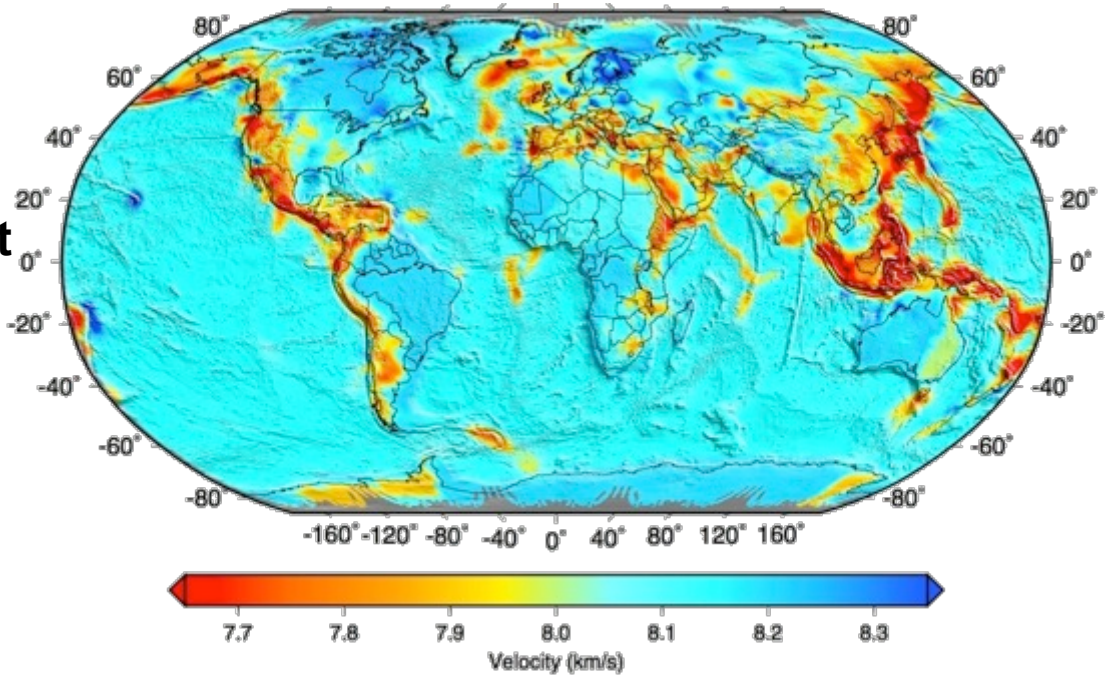
J. Zucca

- Infrasound
  - Time-varying atmosphere
  - Affected by 3D variations in winds and temperatures



3D Seismic Models: RSTT

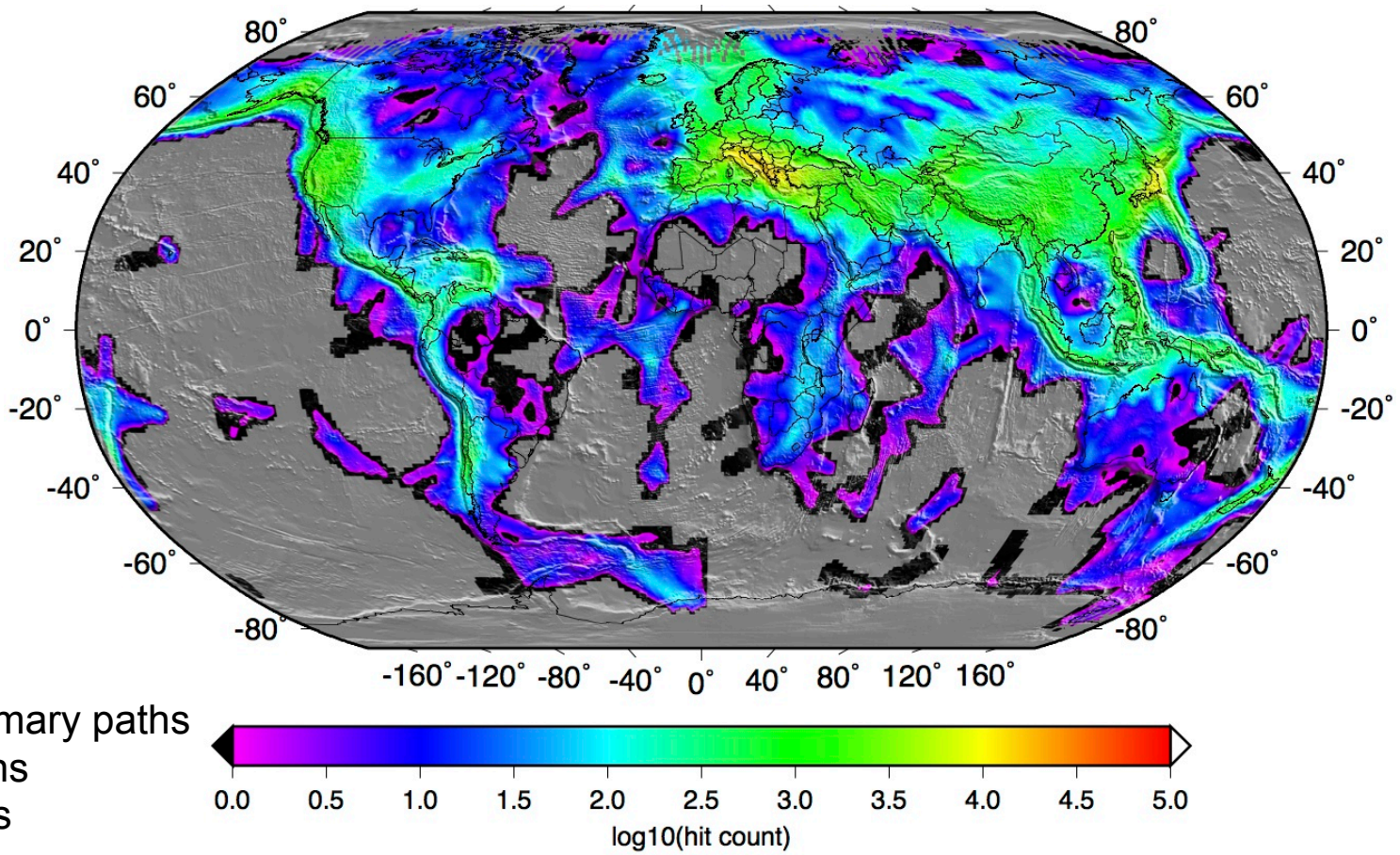
- **Regional Seismic Travel Time (RSTT)**
  - Fast, accurate travel-time predictor for regional phases (Pn, Sn, Pg, Lg/Sg)
- **Multi-lab Collaborative Effort**
- **International Outreach (CiK)**
  - Argentina 2012
  - American Geophysical Union, Meeting of the Americas 2013
  - Science & Technology Meeting 2011, 2013



http://www.sandia.gov/rstt

- Code by S. Ballard
- Myers et al. (2010)

Ray Coverage (Pn)

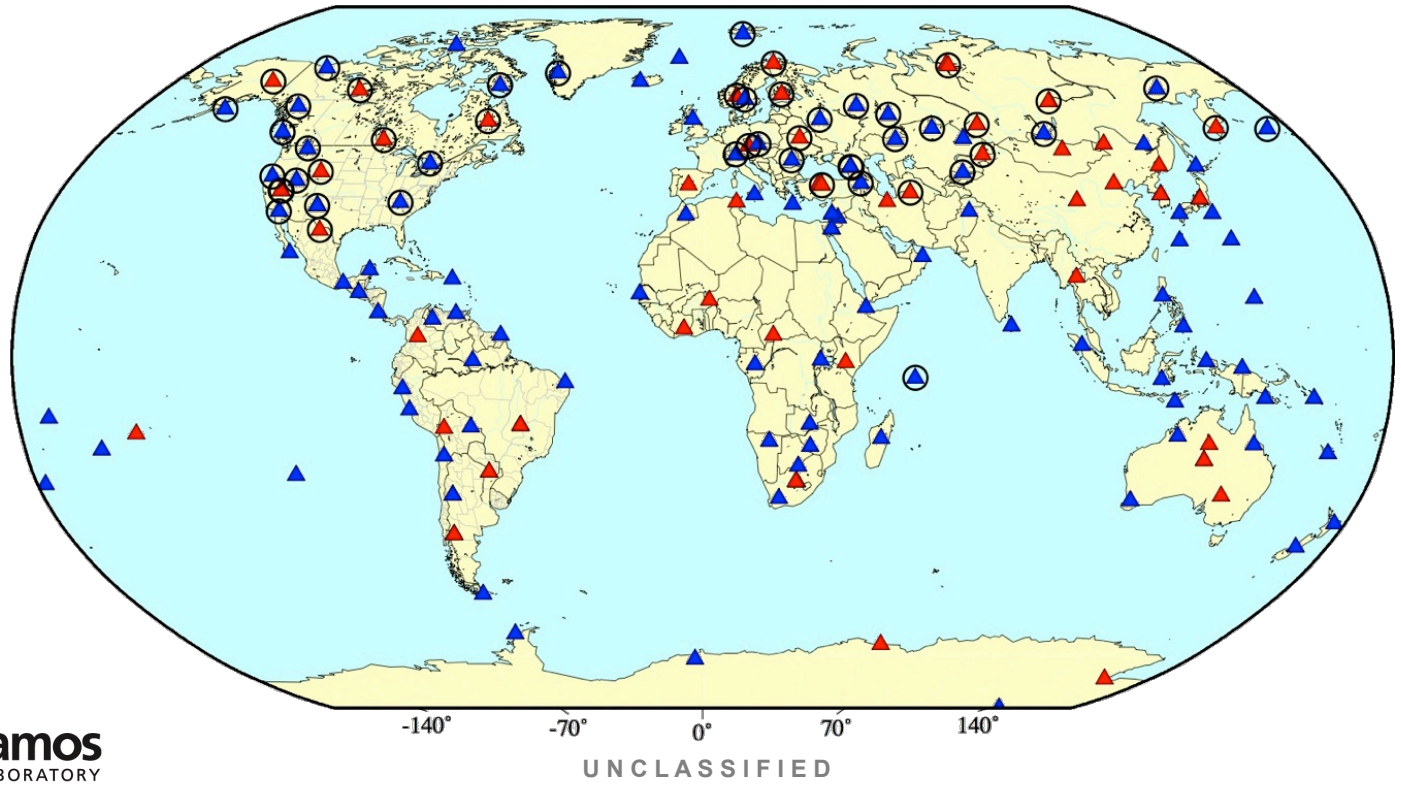


355K summary paths
11K stations
25K events

Source-Specific Station Corrections (SSSCs)

SSSCs were developed for a select set of IMS stations in Eurasia and North America

Current work is expanding to other regions



Station with SSSC

Primary
Auxiliary

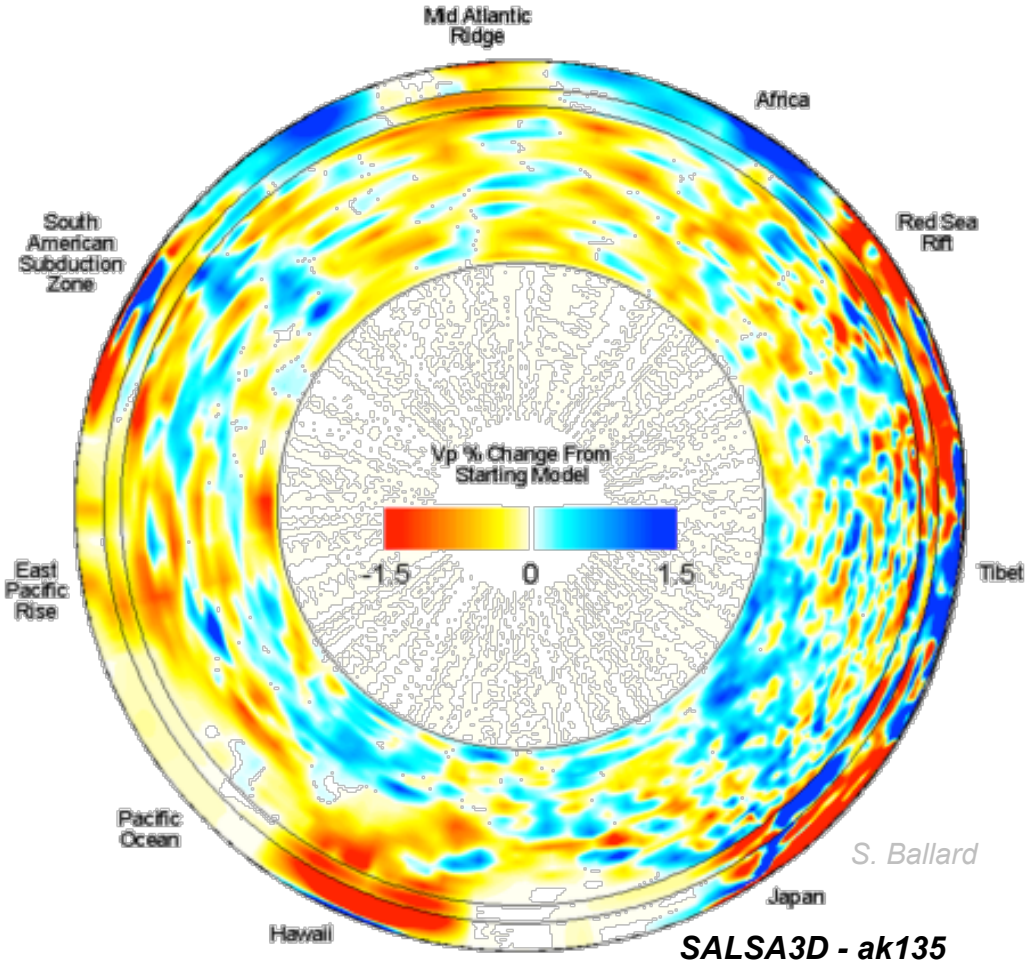
Los Alamos NATIONAL LABORATORY EST. 1943

RSTT Conclusions

- **RSTT Tomography has been performed for all regional phases (Pn, Sn, Pg, Lg) globally.**
- **RSTT tomography velocity patterns are consistent with known tectonic patterns.**
- **RSTT provides an extensible framework to provide accurate regional travel time calculations for all IMS stations.**
- **The RSTT model is "global" but has only been "calibrated" in areas where ray coverage is adequate.**
  - Need more data in other areas of the world for tomography calibration.
  - Ground truth events are needed in many areas to help fill in gaps and produce a model with more consistent global data coverage.

SALSA3D (SAndia LoS Alamos)
Global 3D Earth Model for Travel Time

- **Sandia and Los Alamos are performing detailed research on global 3D earth models for improving travel time predictions and seismic location anywhere in the world.**
  - Several techniques being investigated
    - Data quality control
    - Tomography Methods
- **Computationally intensive**
  - Distributed computing necessary



SALSA3D - ak135
Median Mislocation Difference (km)

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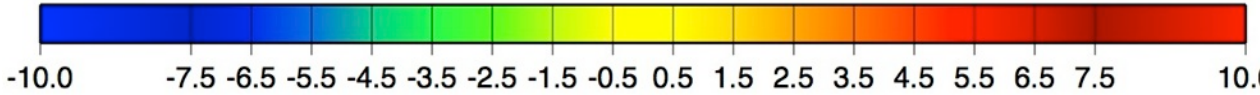
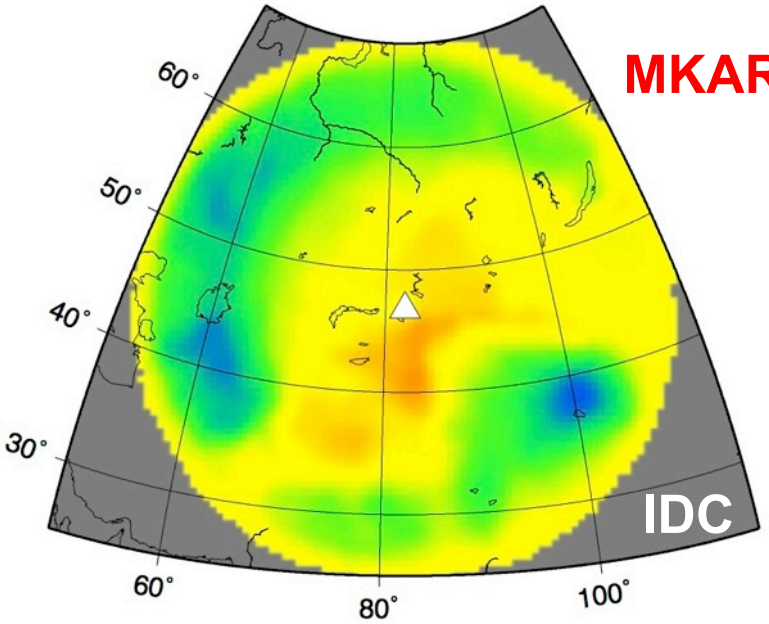
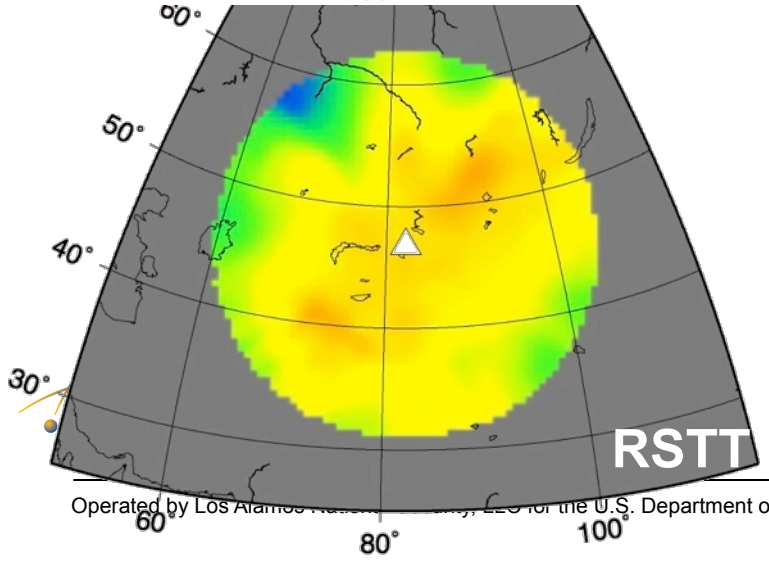
Comparison of IDC SSSCs to RSTT Predictions

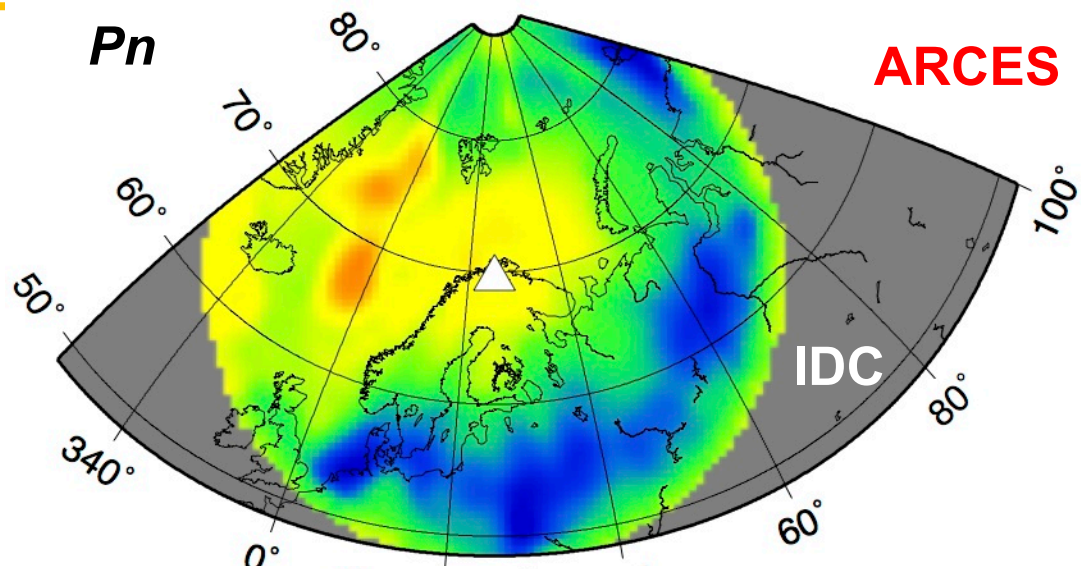


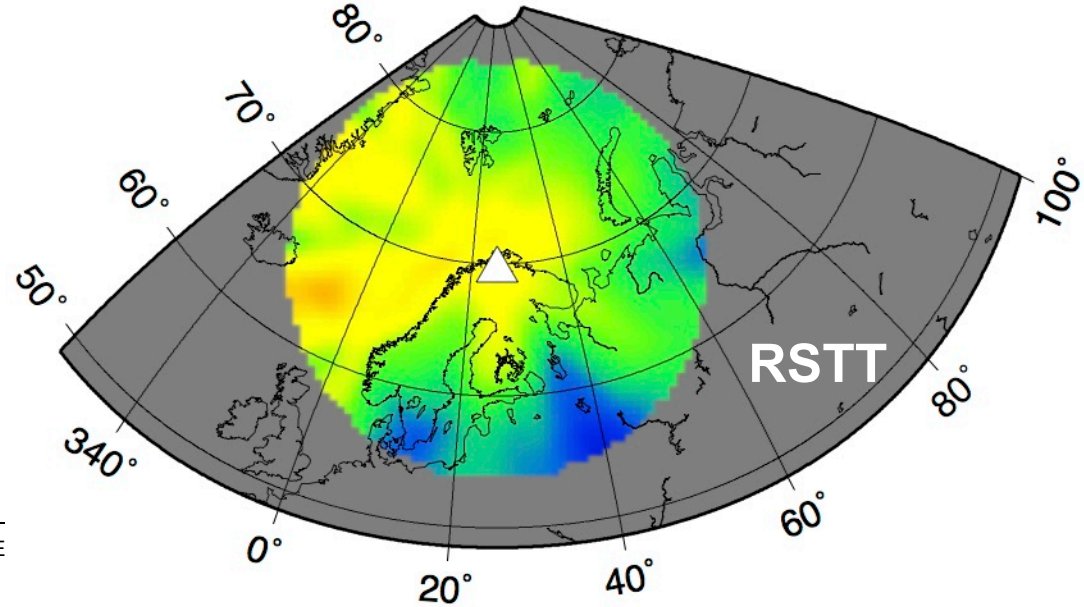
Correction relative to *ak135* (s)



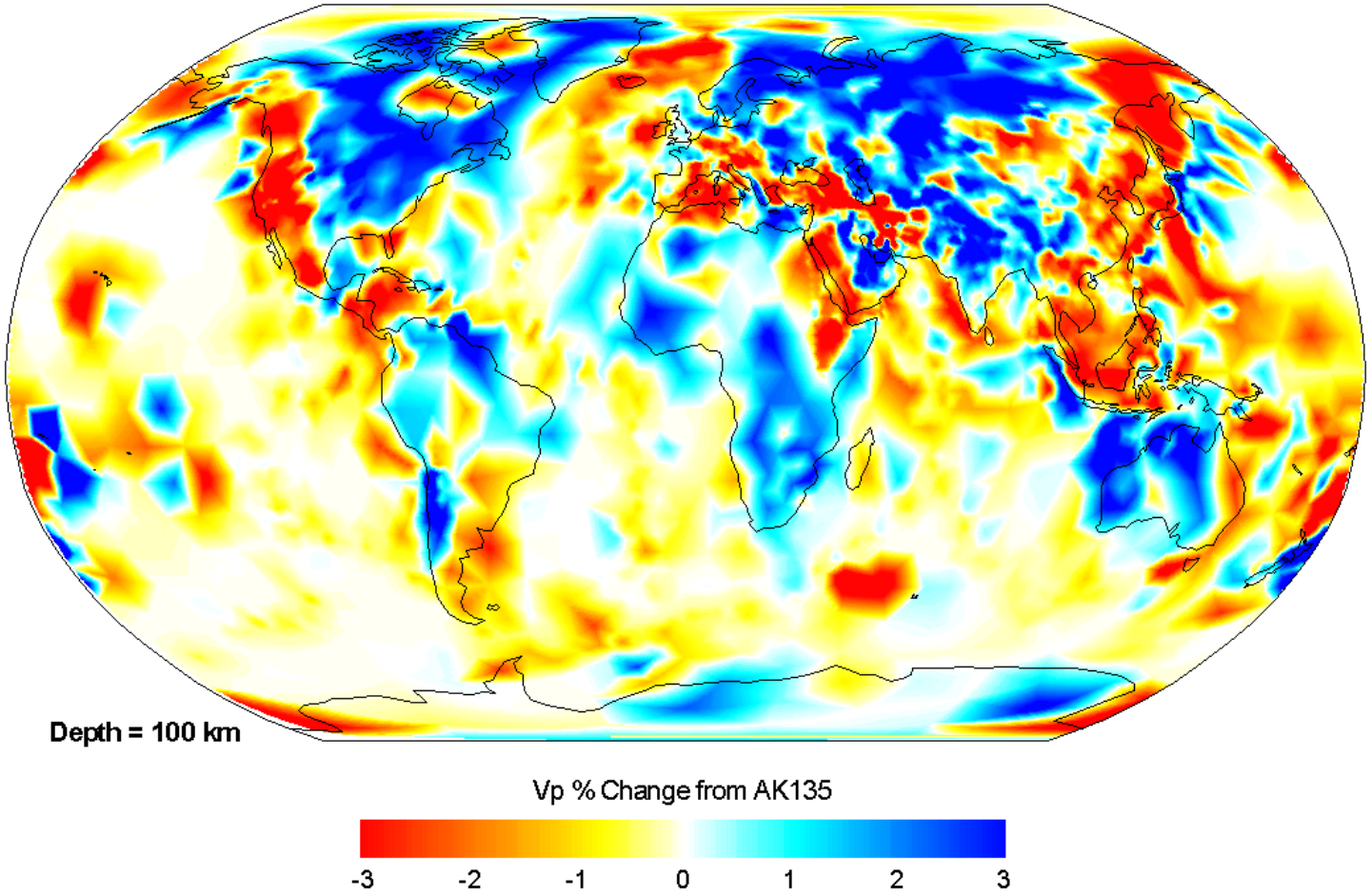


Pn

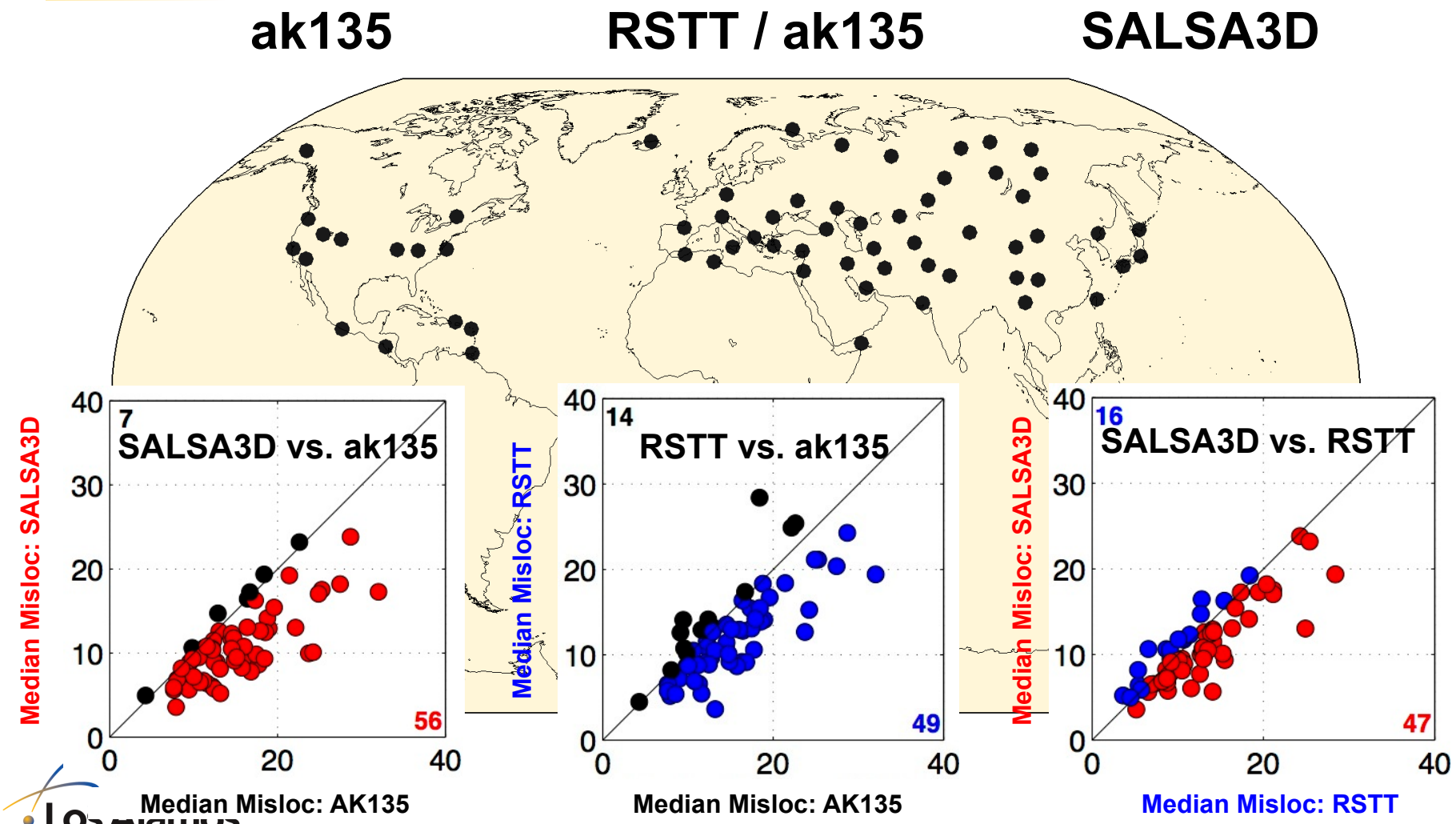




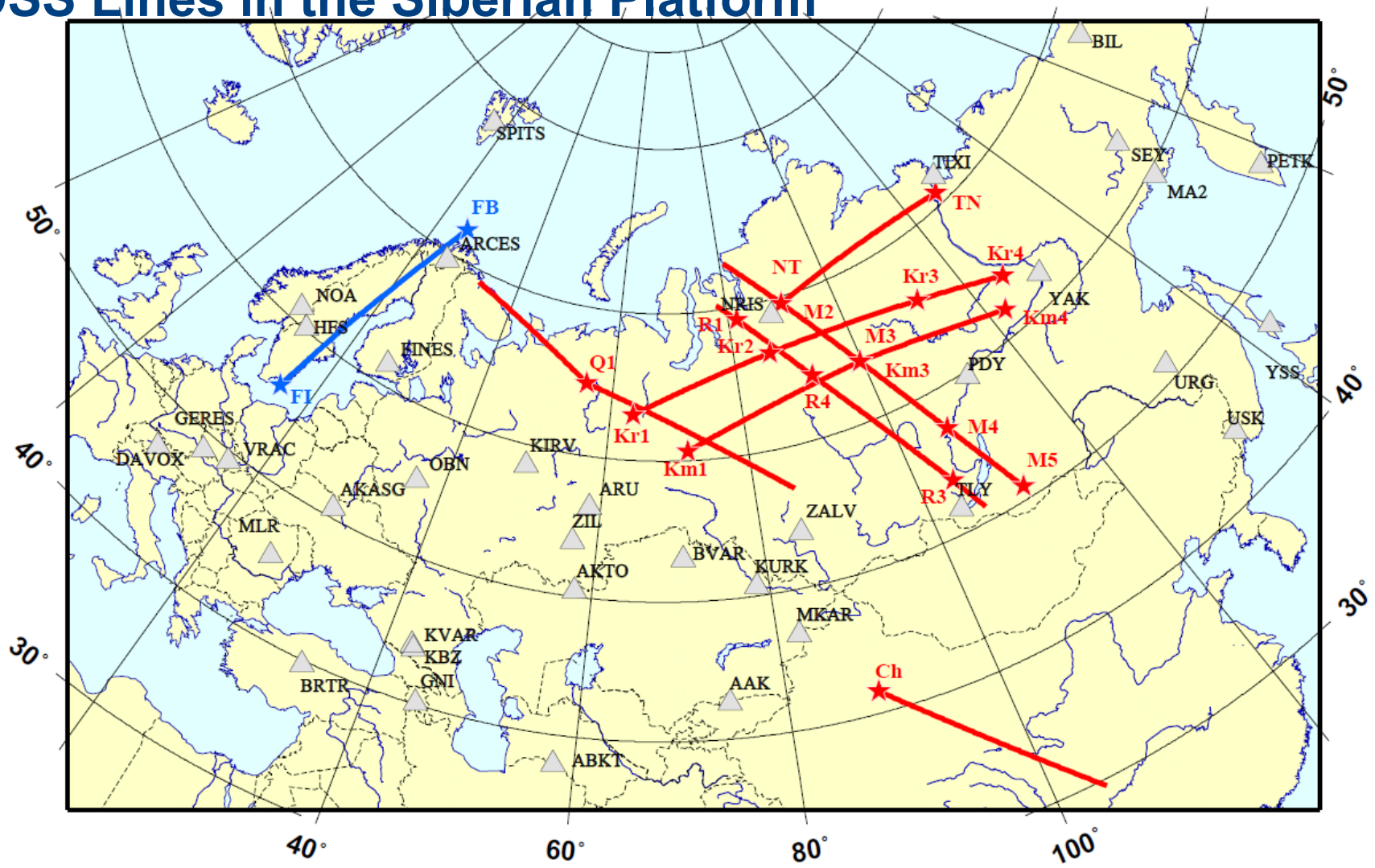
SALSA3D



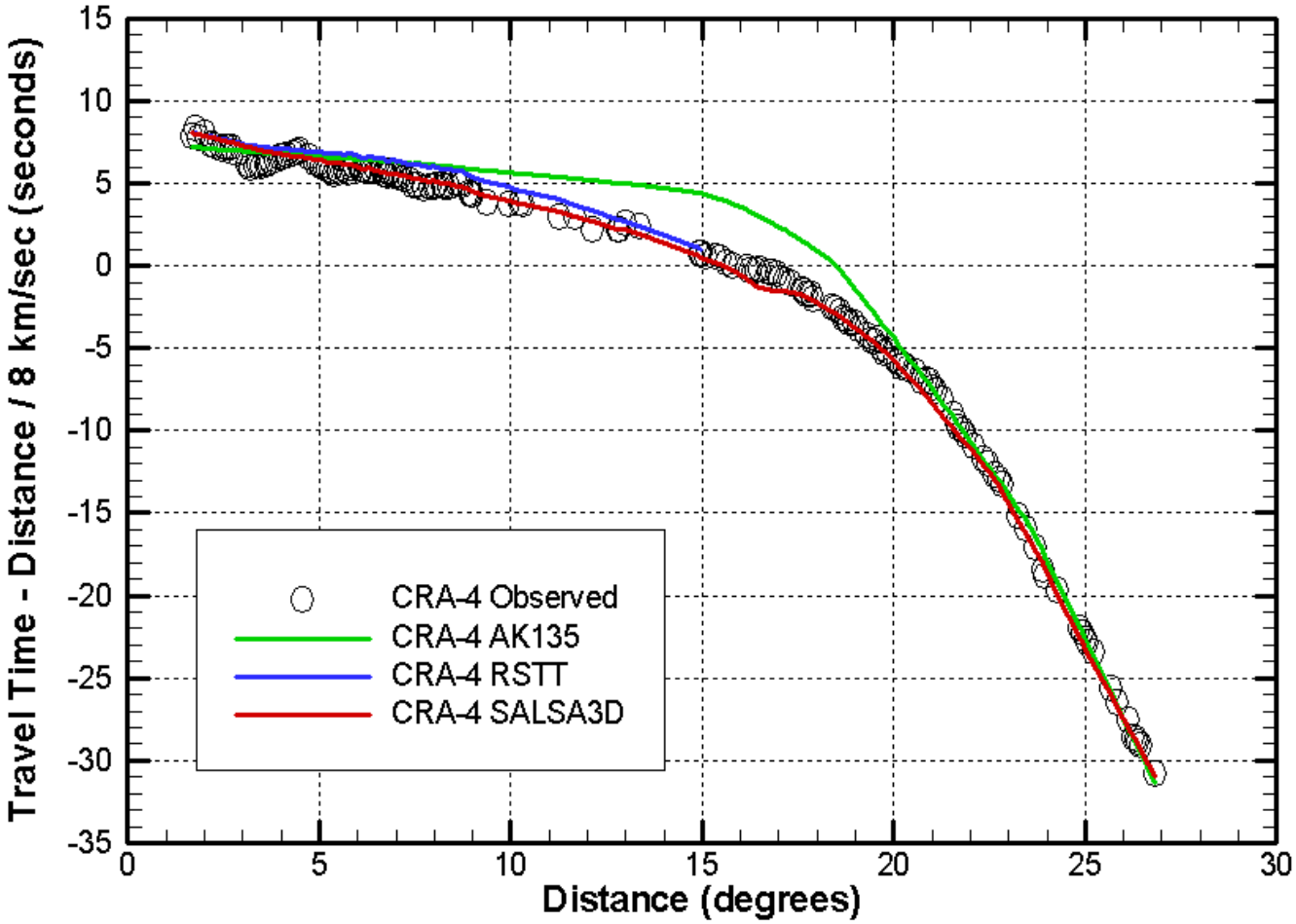
Validation and Model Comparison



DSS Lines in the Siberian Platform

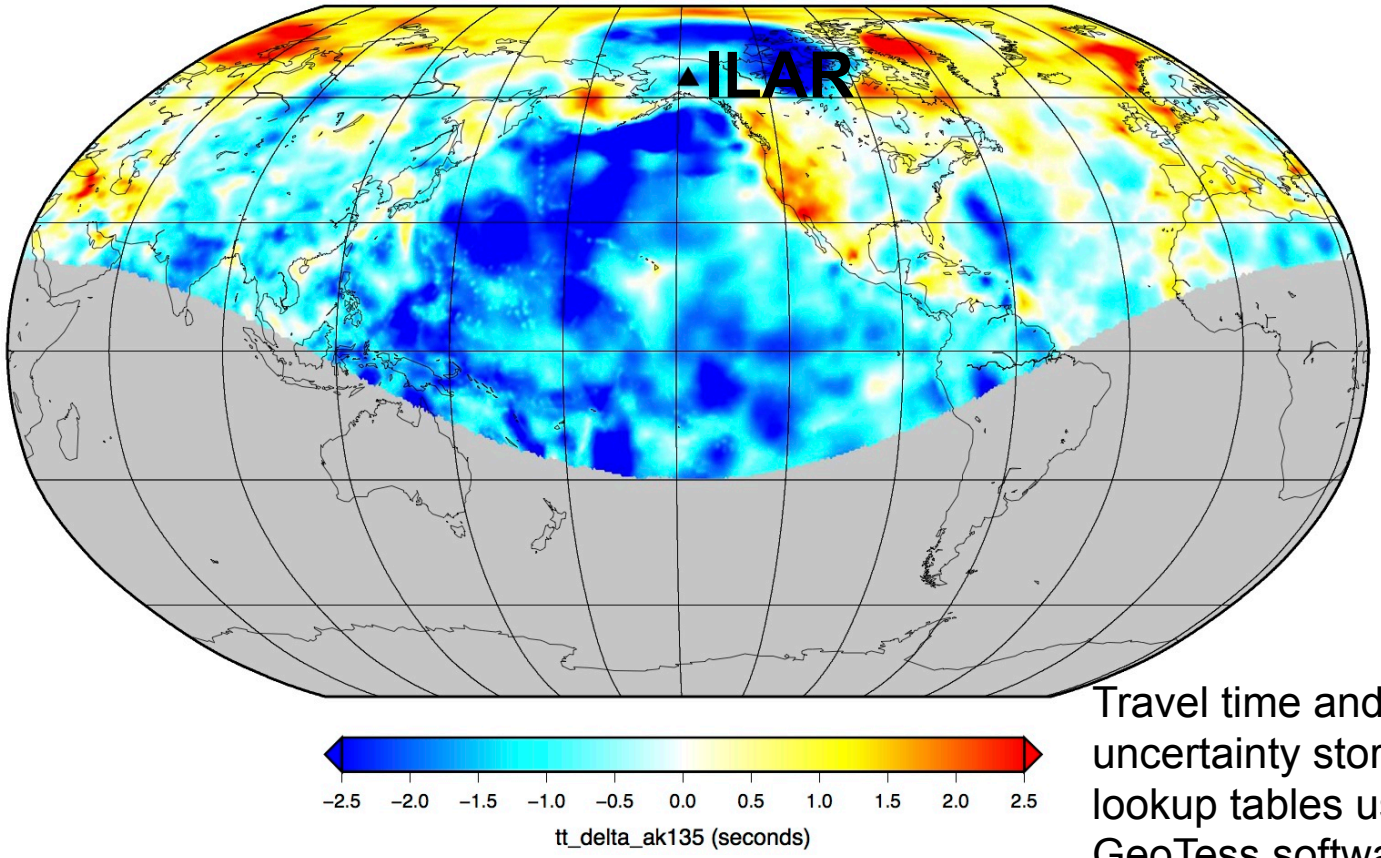


DSS Line CRA-4 Comparison



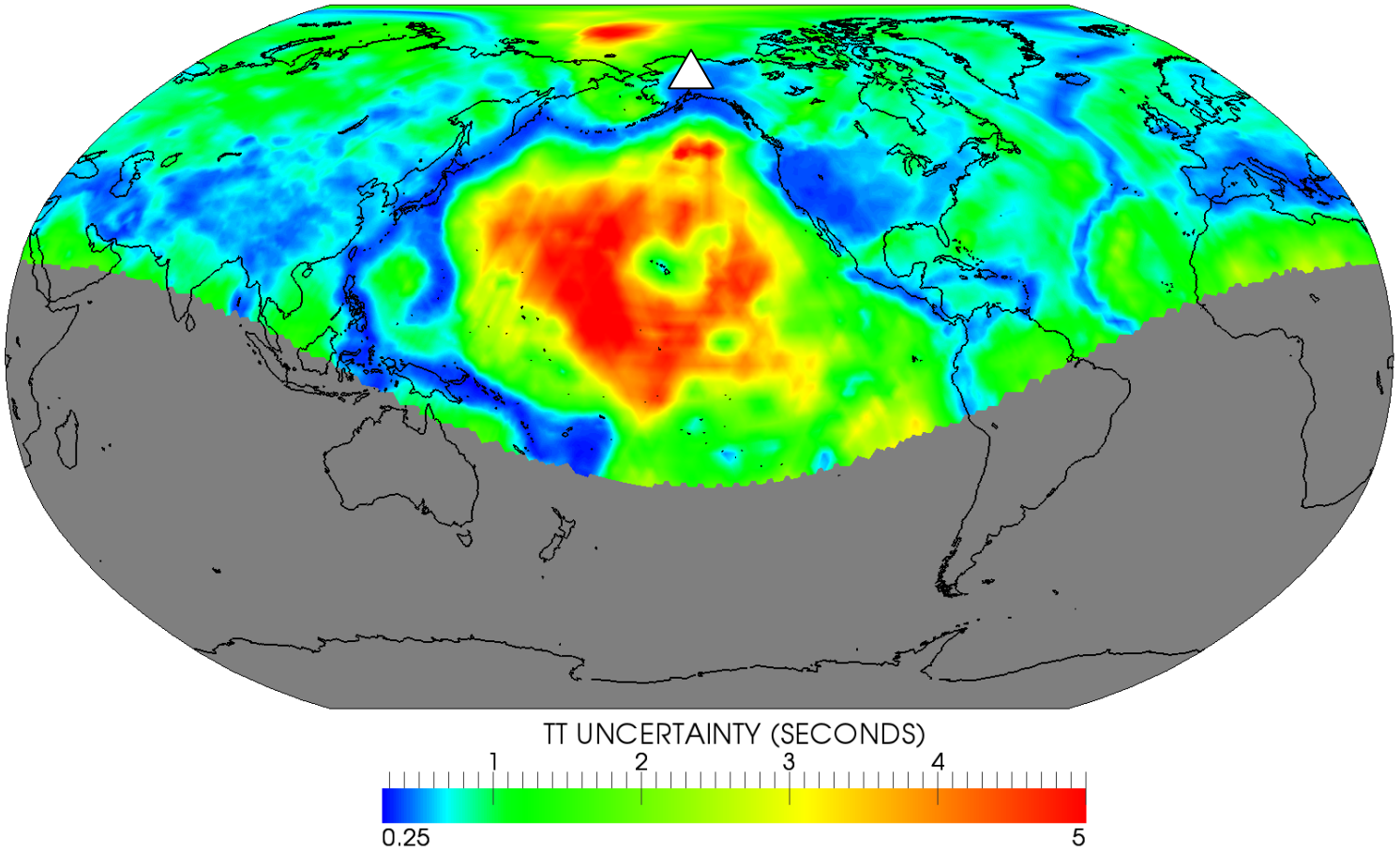
Travel Time Δak135

The most likely way the IDC would implement a 3D model is via travel time lookup tables for their static network.



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

Travel Time Prediction Uncertainty

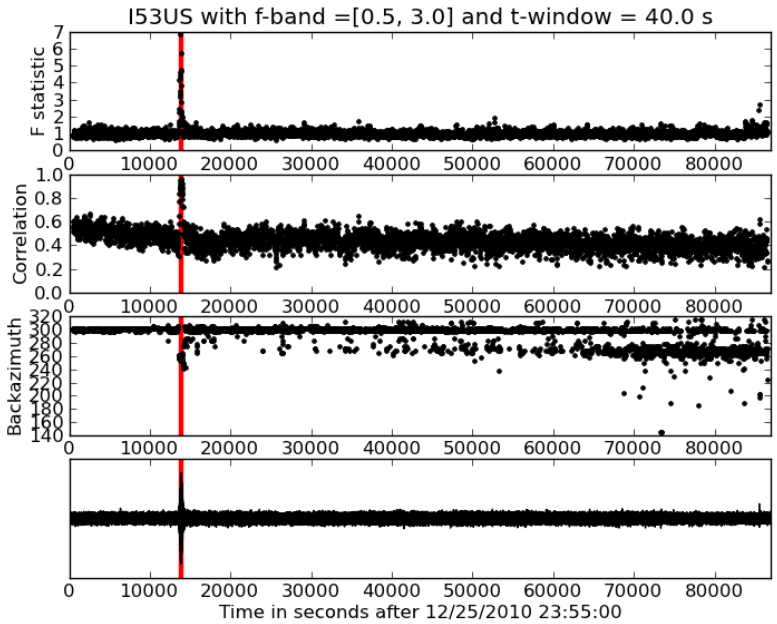


SALSA3D Conclusions

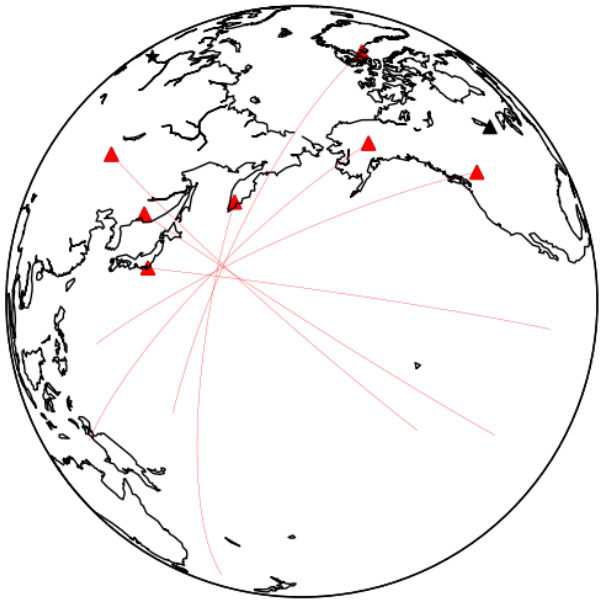
- SALSA3D is a 3D multi-resolution model of the compressional wave speed in the Earth constructed with the goal of improving the accuracy and precision of seismic event location.
- SALSA3D successfully images many tectonic features within the Earth.
- Unambiguous improvement in travel-time prediction and event location compared to ak135 and RSTT/ak135, especially for events observed by a network of stations that is sparse or has poor geometry (e.g., IMS).
- 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).

Infrasound Data Processing: An example event

At LANL we are developing an automatic infrasound data processing system to help provide guidance to CTBTO



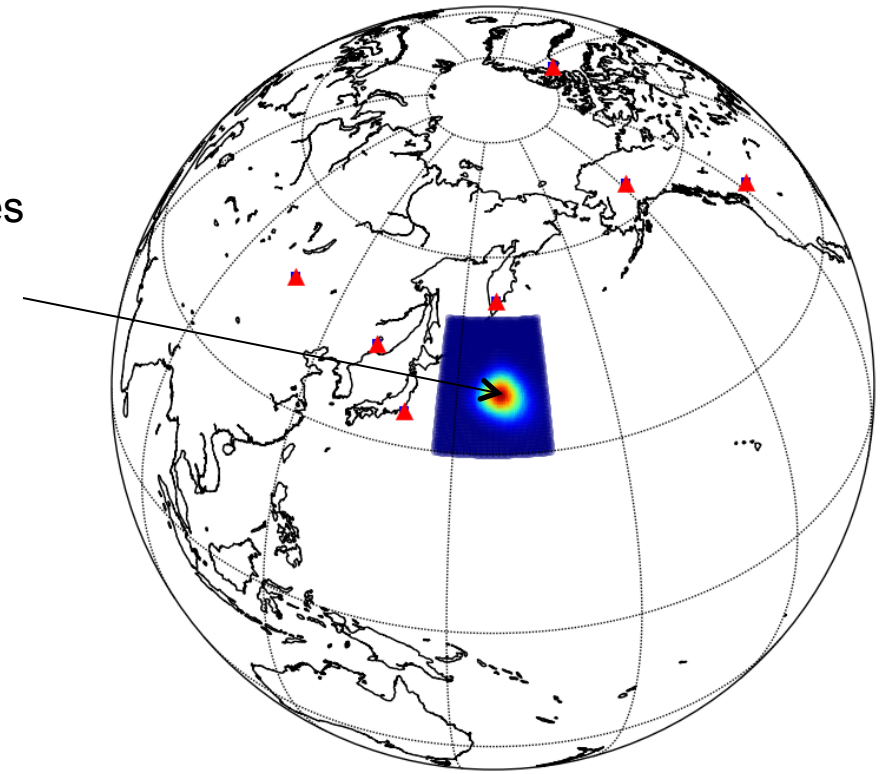
Detection uses a time-varying noise model



Association uses graph theory to provide scalability

Infrasound Data Processing: An example event

Our method provides accuracy and precision using a Bayesian scheme

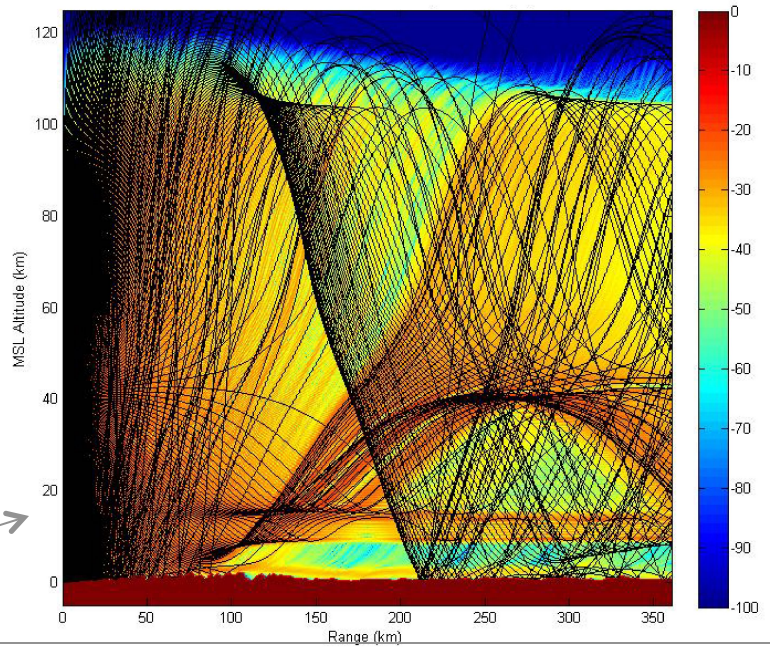


The LANL Bayesian Infrasound Source Locator (BISL) is the state-of-the-art method in infrasound location.

Infrasound Location

Uncertainties in the time-varying atmosphere necessitate a probabilistic approach to infrasound location.

Effects on infrasound propagation include 3D temperatures, winds, topography



BISL is based on the following features:

Advantages of infrasound:

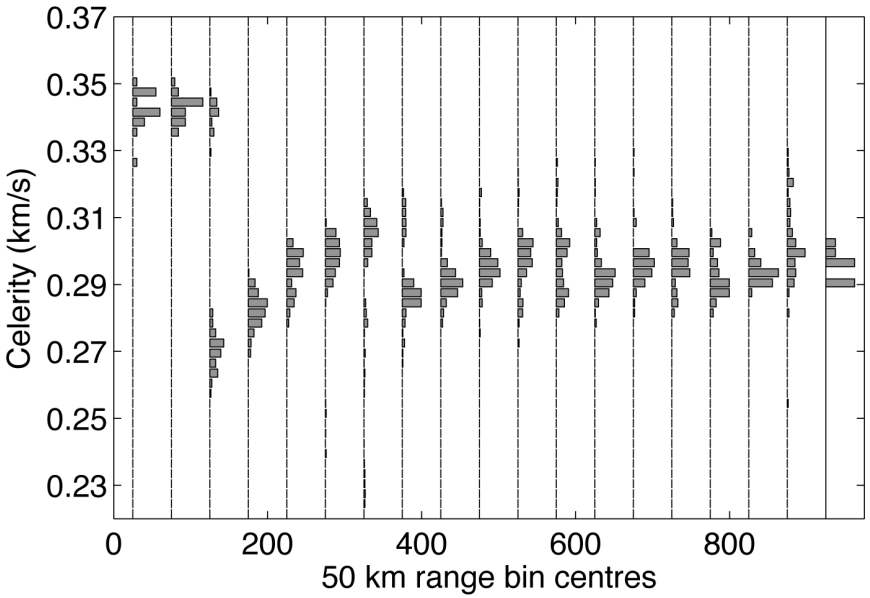
- Accurate back azimuths
- Arrival times contain complementary information

Disadvantage of infrasound:

- Propagation depends on atmospheric properties that, at short time and spatial scales (e.g., wind gusts), we will likely never know deterministically

How does BISL work?

- **Data for event**
  - Minimize residuals between modeled arrival times and bearings and measured arrival times and bearings given some atmospheric model
- **Priors from atmospheric modeling**
  - Use multiple years of atmospheric models to characterize the infrasound propagation in a statistical way
- **Bayes Theorem**
  - Combine data with priors to calculate uncertainty region

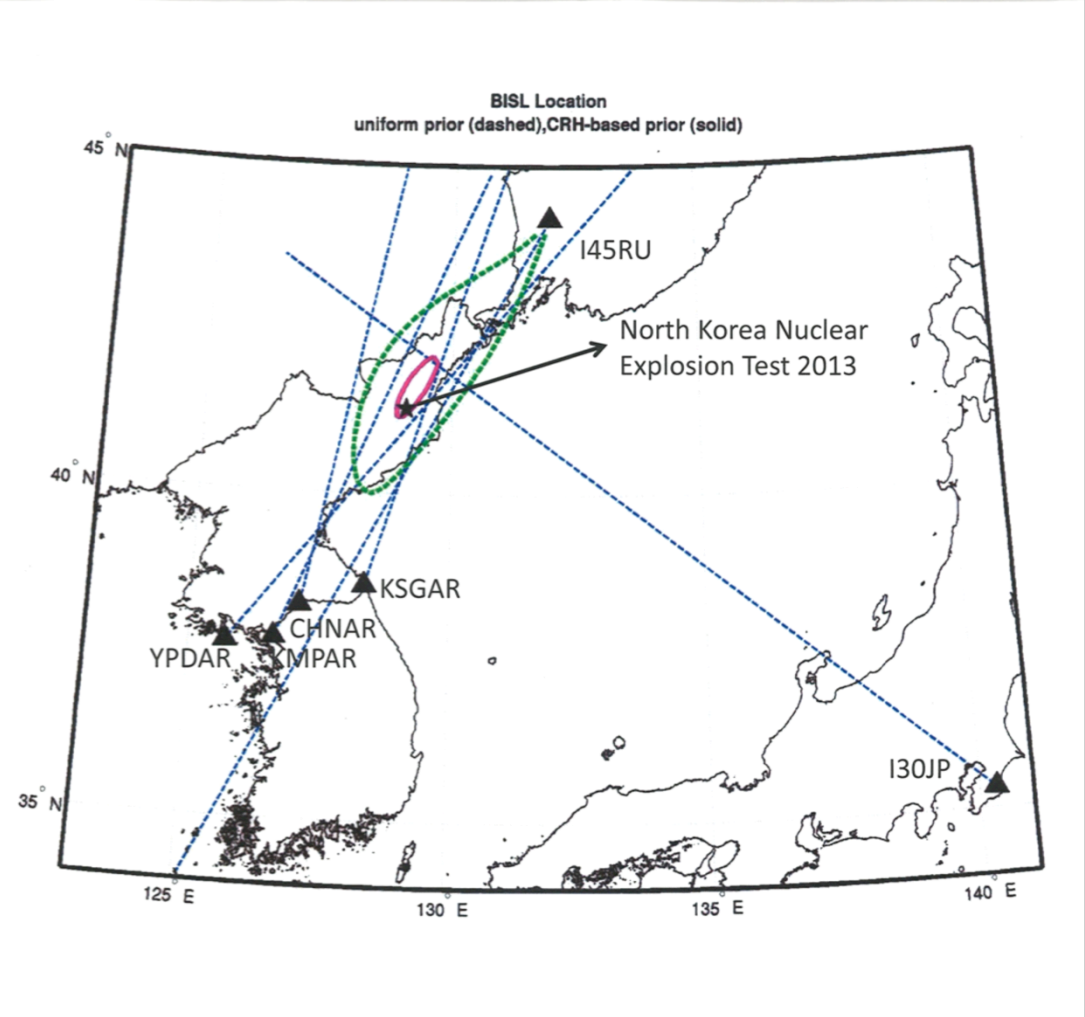


BISL uses a model for how the infrasound propagation varies with range in the form of Bayesian priors.

BISL: Application to the 2013 DPRK Test

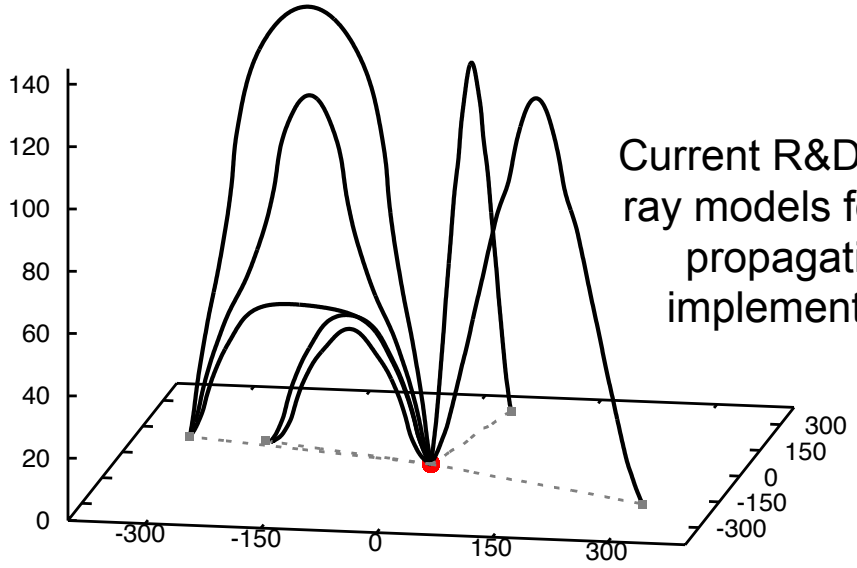
Green contour – 95% uncertainty region using BISL 1.0

Magenta contour – 95% uncertainty region using BISL 2.0



BISL: Ongoing Research…

- Model enhancements – capture additional physics
- Account for bearing bias due to cross winds
- Implement efficient numerical implementation & look-up tables
- Combine infrasound with seismic localization in Bayesian framework



Current R&D on improved ray models for infrasound propagation will be implemented in BISL