Regional Seismic Travel Time (RSTT) Software Summary Sheet

National Nuclear Security Administration

What is RSTT?

RSTT is a software package that improves the accuracy of regional seismic travel time prediction and event location. The software package includes a computerized representation of 3-dimensional seismic wave speed for Earth's crust and shallow mantle (the outer-most 100 to 200 km of the Earth) and a computer code to calculate travel times for waves that are commonly used to locate events. RSTT was designed with real-time monitoring in mind and travel times can be computed on the fly in approximately 1 millisecond. Technical details can be found in a published paper (Full reference on next page).

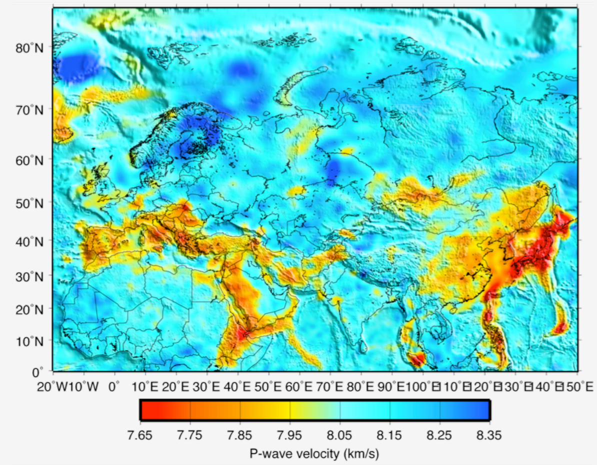

Figure 1. Map of P-wave velocity variations across Eurasia and North Africa. Deviations from constant wave speed result in regional travel time error, which cause event location errors.

How Does RSTT Advance Monitoring?

RSTT advances monitoring by allowing regional data (within 1500 km of an event) to be effectively used to improve location accuracy. After tomographic calibration, RSTT accounts for the extreme variability in wave speed near Earth's surface (Figure 1) and consequently improves travel time prediction and location accuracy.

The largest improvement in location accuracy is achieved when RSTT is used with a regional network. Improvement in location accuracy is also achieved for global networks like the International Monitoring System where at least a few stations are likely to be within regional distance of any given event. Because signals are more reliably detected at regional distances, the importance of regional distance stations (and RSTT) grows as event magnitude decreases.

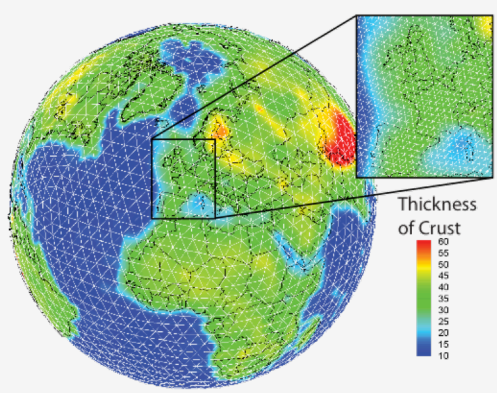

Figure 2. The RSTT model is defined on a global tessellation mesh. An efficient computer code is used to calculate regional travel times and researchers can use the code to extract wave speed velocities and depths to geological layers.

RSTT Wave Speed Calibration

The RSTT tessellation mesh (Figure 2) is inherently global, and wave speed profiles at each tessellation node must be adjusted to ensure improved RSTT prediction accuracy. Wave speed is calibrated using tomography, which is a mathematical imaging method similar to that used in a medical CAT scan. Well- located seismic events (most commonly earthquakes) are used as sources. Wave travel time is calculated by subtracting the estimated time of event occurrence from measured arrival times of regional waves. The tomographic procedure optimizes wave speeds so that the average difference between observed and predicted travel time is minimized.

Extending RSTT Calibration

The ultimate goal of the RSTT effort is global calibration of the four most prominent regional phases used in monitoring (Pn, Pg, Sn, Lg). Calibration of these four phases will result in calibration of P-wave and S-wave speeds in the Earth's crust and shallow mantle. Tomographic calibration to date has been conducted in Eurasia for the four regional phases. In North America, tomographic calibration has been conducted for Pn and is still needed for Pg, Sn, and Lg.

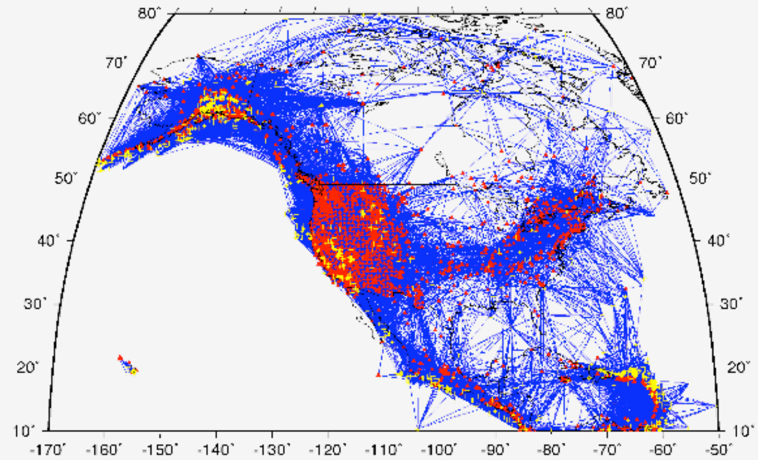

Figure 3. Event-to-sensor ray paths for an example RSTT tomography (calibration) data set. Tomography is used to adjust model wave speed to fit wave travel times for a high-quality data set.

Extension of RSTT calibration to new regions is being pursued through international collaborative efforts. Such efforts include the compilation of new tomography data sets (see Figure 3), working with the U.S. national laboratories to create new or updated RSTT models via tomography, and by assessing how well models improve travel-time prediction and seismic location accuracy.

Computational Considerations

The code used to compute travel times and access the Earth representation is written in C++ with interfaces in C++, Java, C and Fortran 90. It is delivered with source code, pre-built binary libraries for either SunOS, Unix or Linux computers, and test programs written in the 4 supported languages. The code also runs on Windows machines using Visual Studio 2008. Model files occupy approximately 10 MB of disk space and require about the same amount of memory to run. Though not multi-threaded, typical runtime to compute a single source-receiver travel time is well under 1 millisecond.

Peer-Reviewed Publication

Myers, S.C., M. L. Begnaud, S. Ballard, M. E. Pasyanos, W. S. Phillips, A. L. Ramirez, M. S. Antolik, K. D. Hutchenson, J. Dwyer, and C. A. Rowe, and G. S. Wagner. A crust and upper mantle model of Eurasia and North Africa for Pn travel time calculation, *Bull. Seismol. Soc. Am.*, **100**, 640-656, 2010.

RSTT Collaboration Details

Myers, S.C, M. L. Begnaud, and S. Ballard. Extending Regional Seismic Travel Time (RSTT) Tomography to New Regions, in *Proceedings of the 2011 Monitoring Research Review: Ground-Based Nuclear Explosion Monitoring Technologies*, LA-UR-11-04823, 342-351, 2011.