Improving the Regional Seismic Travel Time (RSTT) Model Through International Outreach

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What is RSTT?

RSTT is a method to predict travel times for regional phases (Pn, Pg, Sn, and Lg)

- Regional distance is between ~150 km and 1600 km
- Regional phases travel in the crust and upper mantle
- Signals are larger amplitude than signals at greater distance (enhanced detection).

IASPEI definitions for phases computed by RSTT


Example regional signal

IASPEI is the International Association of Seismology and Physics of the Earth’s Interior
What does RSTT do?

- Travel time prediction errors are higher at regional distances than at other distances.
- Using regional data often increases epicenter error.
- RSTT reduces travel-time prediction errors to levels comparable to those observed at teleseismic distances.

Modified from Rodi and Myers (2013), Geophys. Jour. Int., 194, 1582-1595
doi: 10.1093/gji/ggt171Geophys
How does RSTT reduce prediction errors?

- The RSTT model reduces travel time prediction error by accounting for 3-dimensional Earth structure.
- The model is built on a global, triangular tessellation with independent velocity profiles at each node.

Interpolation of layer depths and velocities renders a 3-dimensional crust overlaying a mantle with laterally varying seismic wave speed.
RSTT travel times are computed in approximately a millisecond

- The RSTT travel time calculation is relatively simple.
- No ray tracing!

\[ TT = \sum_{i=1}^{N} d_i s_i + \alpha + \beta + \gamma \]

\[ \gamma = \frac{c^2 X_m^3}{24 V_0} \]

Model cross section and representative Pn ray path

\( d = \) path increment immediately below crust/mantle boundary.
\( s = 1/\text{velocity} \)
\( \alpha = \) source-side portion of ray
\( \beta = \) receiver-side portion of ray
Tomography is used to adjust model parameters for optimal travel time predictions

- RSTT tomography adjusts
  - Mantle velocity
  - At the Moho
  - Gradient
  - Crustal slowness

Tomographic system of equations

\[
\begin{bmatrix}
\frac{x_1^1}{24V_oX_m} & \cdots & \frac{x_1^N(X_m)^3}{24V_oX_m} & \frac{Q}{\sum_{p=1}^{N_p} t_{1p}} & \cdots & \frac{Q}{\sum_{p=1}^{N_p} t_{Np}} \\
\vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
\frac{x_N^K}{24V_oX_m} & \cdots & \frac{x_N^K(X_m)^3}{24V_oX_m} & \frac{Q}{\sum_{p=1}^{N_p} t_{1p}} & \cdots & \frac{Q}{\sum_{p=1}^{N_p} t_{Np}} \\
\end{bmatrix}
\begin{bmatrix}
\begin{bmatrix}
s_1 \\
\vdots \\
s_N \\
\end{bmatrix} \\
\begin{bmatrix}
t_1 \\
\vdots \\
t_N \\
\end{bmatrix} \\
\begin{bmatrix}
c_1 \\
\vdots \\
c_N \\
\end{bmatrix} \\
\begin{bmatrix}
a_1 \\
\vdots \\
a_N \\
\end{bmatrix}
\end{bmatrix}
\]
RSTT workshops introduce regional experts to the RSTT model and methods

Participating Countries to date (66)

Algeria  Algeria  Argentina  Australia  Armenia  Azerbaijan  Bahamas  Bolivia  Brazil  Cameroon  Chad  Chile  Columbia  Comoros  Congo  Cook Islands  Costa Rica  Djibouti  Dominican Republic  Ecuador  Egypt  Ethiopia  Fiji  France  Georgia  Ghana  Guatemala  Haiti  Hungary  Iraq  Ireland  Italy  Jamaica  Jordan  Kazakhstn  Kyrgyzstan  Libya  Malaysia  Madagascar  Mexico  Micronesia  Mongolia  Morocco  Mozambique  Nauru  New Zealand  Norway  Panama  Peru  Papua New Guinea  Philippines  Samoa  Solomon Islands  South Africa  South Korea  Tajikistan  Tanzania  Tonga  Tunisia  Turkmenistan  Uganda  United Kingdom  United States  Uzbekistan  Vanuatu  Venezuela  Zambia

San Juan, Argentina

Almaty, Kazakhstan
Typical training agenda

- Introduction to the RSTT model and method
- Utility of RSTT to CTBTO, NDCs and national networks
- The need for model and data contributions
- Location examples using the ISC locator
- Instruction in how to extract and modify RSTT model parameters
- Hands-on exercises involving
  - Calculation of travel times using the RSTT code
  - Extraction and modification of RSTT model parameters
  - Event relocation
- Review of data contributed during the workshop

Evening activities during RSTT workshop in San Juan, Argentina
Studies of local/regional structure can be incorporated into the RSTT model.

- Crustal thickness is generally not resolved by RSTT tomographic data sets.
- Significant updates to crustal thickness were incorporated into the RSTT model as a result of workshops in South America.

Contributed by M. Assumpcao
Data coverage is significantly improved by contributions provided at RSTT workshops.
RSTT data coverage is good in continents
... holes in continental data coverage remain
Summary

- RSTT provides an extensible framework to provide accurate travel time calculations for Pn, Pg, Sn, and Lg phases.
- Millisecond computational time removes the need for pre-computation of travel time corrections
  - Enables use with a flexible network, e.g., national networks
- CTBTO outreach efforts and workshops
  - Training for RSTT use with the ISC locator
  - Contribution of local and regional models
  - Contribution of data for improved tomography.
    - Contributed to the ISC ground-truth database.
- The RSTT model is a work in progress
  - Further efforts can significantly improve RSTT prediction