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SALSA3D Software Tools for Model Interrogation, Event Location and Travel-time Computation

Nathan Downey*[1], Rigobert Tibi[1], Sanford Ballard[1], James Hipp[1] and Mike Begnaud[2]

[1]Sandia National Laboratories, Albuquerque, NM, USA [2]Los Alamos National Laboratory, Los Alamos, NM, USA

*Corresponding Author, Contact: njdowne@sandia.gov

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Introduction

A goal of the SAndia LoS Alamos 3D (SALSA3D) tomographic project is to provide support for the use of the SALSA3D models and software tools to monitoring agencies and the seismological community.

There are three primary products of SALSA3D:

1. The SALSA3D velocity models
2. Travel-time lookup tables for seismic phases
3. Software tools, including:
   a) Tools for model representation (GeoTESS)
   b) Travel time computation / ray tracing (pCalc)
   c) Event Location (LocOO3D)

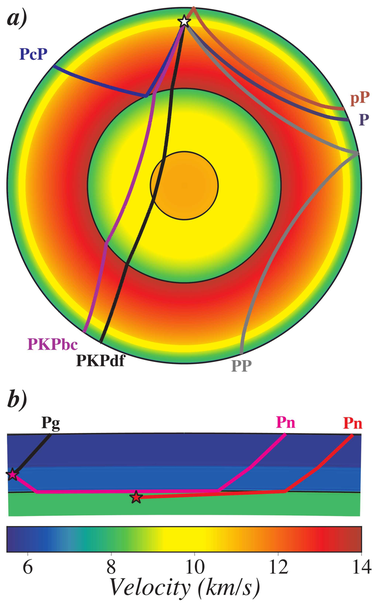
Here we present the locations where these products will be distributed and describe how to access the support materials.

Velocity Model Releases

The primary method by which the SALSA3D models are released is on a dedicated webpage (Figure 1):

www.sandia.gov/salsa3d

Figure 1: *Images of the SALSA3d webpage located at www.sandia.gov/salsa3d. This website is the location where the SALSA3D models, travel-time tables and software products are distributed.*



c)

SALSA3D V2

Phase	Number	Percent
P	7,517,183	76
Pn	2,436,049	24

SALSA3D V3

Phase	Number	Percent
P	7,517,183	60
Pn	2,436,049	20
PKPdf	808,001	6
pP	607,032	5
PP	423,675	3
PKPbc	379,044	3
PcP	283,123	2

Figure 2: *Diagram of the seismic phases used to construct the SALSA3D P-wave velocity models.* ***a)*** *Diagram showing the teleseismic phases used in the inversions* ***b)*** *Diagram highlighting the crustal phases used in the SALSA3D models.* ***c)*** *Table showing the number of phase arrivals used in SALSA3D model construction. Currently, the models and travel-time tables for SALSA3D V3 are distributed on the website.*

Currently, we distribute the latest, V3 (see Figure 2), SALSA3D P-wave velocity model along with the inversion starting model, AK135, in GeoTESS format. Future releases will include models with different depth-phase surface bounce points, a whole-Earth shear-wave velocity model and any updates to the SALSA3D P-wave velocity model that incorporate additional seismic phases.

Travel Time Lookup Surfaces

These "surfaces" are pre-computed travel times through the SALSA3D model from a select station to any location where a seismic event of interest could occur (Figure 3). We distribute these tables on the SALSA3D website (Figure 1) for the phases P, PcP, PKPbc, and PKPdf for the stations in the primary and auxiliary International Monitoring System (IMS) stations. Phases pP and PP will be released in the future. Future releases will also include surfaces for phases incorporated in future SALSA3D models (e.g. PKPab, PPP, and others) and additional surfaces for IMS stations as they become certified.

These surfaces are provided in two formats:

1.GeoTESS – Full 3D lookup tables (include depth as an event parameter)

2. SSSC – 2D lookup tables (epicenter only)

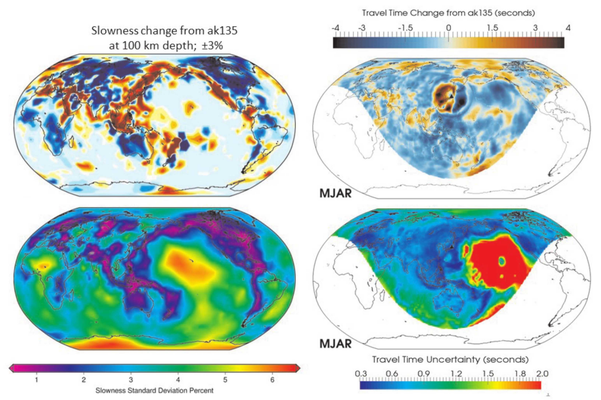


Figure 3: *(Left) Plots of the SALSA3D model P-wave velocity and its uncertainty at 100km depth. (Right) Plots of the travel-time lookup surface for phase P at station MJAR (Nagano, Japan) along with the associated travel-time uncertainty. The white areas in the right plots indicate the regions where the P phase does not propagate because the ray-paths intersect the core-mantle boundary and the P phase converts to other phases (PKP, PcP, etc.; see Figure 2)*

Software Tools

GeoTESS

GeoTESS is a model representation software package suited to Earth models. GeoTESS already has an operating webpage (see Figure 4) located at:

www.sandia.gov/geotess

The GeoTESS webpage contains:

1. Stand-alone versions of GeoTESS software.
2. A GeoTESS C/C++ API for custom software.
3. A detailed user manual.

Figure 4: *Images of the GeoTESS webpage and user manual available at www.sandia.gov/geotess*

pCalc and LocOO3D

pCalc calculates travel times through whole-earth velocity models in a variety of formats, including the GeoTESS format used in SALSA3D. LocOO3D can use these same velocity models to compute single event locations using an iterative least-squares approach. Both these software products will be distributed through the SALSA3D webpage beginning in 2019. Both these programs will be distributed with detailed user manuals and a suite of test events:

1. The 2017 North Korean nuclear test.
2. A 2018 Utah event, with expert analyst picks.
3. An explosive event at the Nevada National Security Site
4. A mid-size Australian event (M_L=5.4)

U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

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