**PREM-PLUS: A collection of programs for computing free oscillations, Love numbers, and some internal parameters including flattening for PREM-like Earth models**

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You can use the programs for your purpose with an acknowledgement and list in the reference the following book where the methodologies are described:

Guo, J.Y. (2025). Physical Geodesy: Global Elastic Deformation of the Earth. Springer.

Note that in a PREM-like Earth model, the parameters are provided as continuous functions in a number of layers with jumps at the boundaries between consecutive layers. Two types of Earth models are available: Discrete and polynomial. Most available models are provided in the folder “Earth\_Models”. Reading the description and data of the PREM (with more information provided) is the best way to understand how the models are provided, and how they are used in these programs.

Reference has been made to the Chinese translation of the book by [Press](https://en.wikipedia.org/wiki/William_H._Press) et al: Numerical Recipes in [C](https://en.wikipedia.org/wiki/C_(programming_language)). The Art of Scientific Computing, 1st Edition, 1988.

The programs are developed under Windows using “Dev-Cpp” which can read the project files with the extension dev. The package “Embarcadero\_Dev-Cpp\_6.3\_TDM-GCC\_9.2”, which can be downloaded from the internet, was used to compile the codes lastly.

The makefiles for Windows Mingw are also provided for users without “Dev-Cpp” installed, e.g., “To\_1km\_Model.makefile” is the makefile for “To\_1km\_Model”. For using a Windows Mingw g++ compiler, the following command compiles the program:

mingw32-make.exe -f "To\_1km\_Model.makefile" all

All programs are on the solution of ordinary differential equations using the Chebyshev Collocation Method. The numbers of collocations points in the layers are stored in the file “xxxxxx\_NumColl.txt”. It can be overwritten while executing the programs.

All parameters of a programs should be assigned in its control file, e.g., “To\_1km\_Model\_Control.txt” is the control file of “To\_1km\_Model”. Besides the outputs assigned in the control file for further usage, the overall inputs and outputs are written to the “result” file of the program, e.g., “To\_1km\_Model\_result.txt”.

For Linux/Unix user, the line “DEL = del” in the .makefile should be modified by replacing “del” by “rm”. The control file should be modified by replacing “\” by “/” for accessing folders.

The following are a list of the programs:

* To\_1km\_Model: Compute a discrete Earth model in one km interval of radial distance by evaluating polynomials (for polynomial Earth models) or by cubic spline interpolation (for discrete Earth models). In the cubic spline interpolation, the first order derivative is set to zero at the Earth center, and the second order derivatives are set to zero at all other boundaries (natural spline).
* Parameters\_Related\_To\_Density: Compute density-related parameters inside the Earth, which are provided as discrete values in one km interval. These include: Mean rho of the sphere within the radius r, the mass of the sphere within the radius r, the gravity at the radius r, the pressure at the radius r, the mean moment of inertia within the radius r, the flattening at the mean radius r, r times the derivative of the flattening with respect to r, and the difference between the axial and equatorial moments of inertia C-A.
* ln\_tidal\_snrei\_static: Computation of the static tidal Love numbers. This is based on Longman’s approach. As the period of the tidal deformation is known, an improvement is to use the dynamic tidal Love numbers.
* ln\_tidal\_snrei\_dynamic: Computation of the dynamic tidal Love numbers.
* slichter\_modes: Computation of the periods of the Slichter modes (for providing the results in the book).
* ln\_loading\_snrei\_static\_Longman: Computation of the static load Love numbers based on Longman’s approach, noting that this approach imposes physics in the outer core.
* ln\_loading\_snrei\_static\_Smylie: Computation of the static load Love numbers based on Smylie and Mansinha’s approach.
* ln\_loading\_snrei\_static\_Smylie\_zero\_interactive: Computation of the static load Love numbers based on Smylie and Mansinha’s approach with an zero interactive option.
* LITH1\_lln\_local\_profile: Computation of the static load Love numbers based on Smylie and Mansinha’s approach using local Earth parameter profiles based on LITH1.0 (in the folder “LITHO1.0”, see below).
* ln\_loading\_snrei\_dynamic: : Computation of the dynamic load Love numbers.
* greens\_function\_loading: Computation of the load Green’s function (in folder Greens\_Function\_Loading).
* free\_oscillation\_spheroidal\_snrei: Computation of spheroidal free oscillation periods and eigen-functions.
* free\_oscillation\_spheroidal\_snrei\_search\_one\_by\_one: Computation of the period and eigen-function of one spheroidal free oscillation mode (if executed without optional input files).
* free\_oscillation\_spheroidal\_snrei\_search\_multiple\_one\_by\_one: A mode of running “free\_oscillation\_spheroidal\_snrei\_search\_one\_by\_one” with optional input files. This computes the periods and eigen-functions of a list of spheroidal free oscillation modes.
* free\_oscillation\_toroidal\_snrei: Computation of toroidal free oscillation periods and eigen-functions.
* free\_oscillation\_toroidal\_snrei\_search\_one\_by\_one: Computation of the period and eigen-function of one toroidal free oscillation mode (if executed without optional input files).
* free\_oscillation\_toroidal\_snrei\_search\_multiple\_one\_by\_one: A mode of running “free\_oscillation\_toroidal\_snrei\_search\_one\_by\_one” with optional input files. This computes the periods and eigen-functions of a list of toroidal free oscillation modes.

REMARK on the free oscillation:

* Free oscillation modes can be first scanned by

free\_oscillation\_spheroidal\_snrei

free\_oscillation\_toroidal\_snrei

Missing ones can be identified and can be searched by

free\_oscillation\_spheroidal\_snrei\_search\_one\_by\_one

free\_oscillation\_toroidal\_snrei\_search\_one\_by\_one

or

free\_oscillation\_spheroidal\_snrei\_search\_multiple\_one\_by\_one

free\_oscillation\_toroidal\_snrei\_search\_multiple\_one\_by\_one

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**Programs in the folder LITHO1.0**

This program computes the load Love numbers using a local Earth parameter profile. These Love numbers are more accurate in the interpretation of local measurements like GNSS measured crustal displacement.

**run under Windows**

**Litho1.0 data**

=>Keep the Litho1.0 data folder litho\_model!!!!

=>Icosahedron\_Level7\_LatLon\_mod.txt

geocentric latitude, geodetic latitude, longitude

=>access\_litho

access\_litho.cpp is modified from access\_litho.cc

compile access\_litho.cpp to access\_litho.exe before running

LITHO1\_profile\_local\_stations.exe (next step)

geocentric latitude, longitude

**Programs**

=>keep all files!

=>LITHO1\_profile\_local\_stations

(1) Edit LITHO1\_profile\_local\_stations\_sontrol.txt (just change values in the example)

Line 1: number of stations

Next number of station lines: Station\_name, geocentric\_latitude, geocentric\_longitude

Last line: end

Remark: no space in name of station, last line must be "end"

(2) compile LITHO1\_profile\_local\_stations to LITHO1\_profile\_local\_stations.exe

and run

local Earth parameter profiles are in folders named using station names access\_litho.exe is called to generate the local parameter profiles

=>LITH1\_lln\_local\_profile

(1) edit LITH1\_lln\_local\_profile\_ctontrol.txt (just change values in the example)

Line 1: lowest degree

Line 2: Highest degree

Line 3: Value of G

Line 4: Seismic period (leave as is)

(2) run LITH1\_lln\_local\_profile.exe

Love numbers will be in the folder of the station! the program

ln\_loading\_snrei\_static\_Smylie\_zero\_interactive.exe

is used. The number of collocation points must be preassigned in the file

ln\_loading\_snrei\_static\_Smylie\_zero\_interactive\_NumColl.txt

The control file is generated by LITH1\_lln\_local\_profile.exe