NM_CT_readme, Jul. 5, 2020, Houwang Tu, NUDT

The program NM_CT.m computes the range-independent modal acoustic field using the Chebyshev-Tau spectral method (NM_CT). The method is described in the article (H. Tu, Y. Wang, Q. Lan et al., A Chebyshev-Tau spectral method for normal modes of underwater sound propagation with a layered marine environment, https://doi.org/10.1016/j.jsv.2020.115784). We have developed program in Fortran version (NM_CT.f90) and Matlab version (NM_CT.m), respectively. Both versions of the program use the same input file “input.txt”, ‘Read_input’ function/subroutine is used to read “input.txt” file. User can make changes to “input.txt” for the desired calculation. It is worth mentioning that the Fortran version of the program calls the subroutine ‘zgeev()’ in the Lapack (a numerical library) to solve the eigenvalues of the complex matrix, so the user needs to install the Lapack on the computer when running NM_CT.f90, and may need to make simple modifications to the Makefile. Both the Matlab and Fortran versions of the program will eventually generate the same format of the binary sound field file “tl.bin”, and the plot_binary_tl.m program can be used to read the sound field binary data and plot.

The “input.txt” file contains the parameters defining the modal calculation. See the following example:

```
Example4                                 !casename
20                                       !Nw (truncation order of water column)
20                                       !Nb (truncation order of bottom sediment)
3500.0                                   !cpmax (maximum phase speed limit)
50.0                                     !freq (frequency of source)
36.0                                     !zs (depth of source)
10.0                                     !zr (depth of special receiver)
3500.0                                   !rmax (receiver ranges(m))
1                                        !dr (discrete step in horizontal direction)
50.0                                     !h_interface (thickness of water column)
100.0                                    !H_bottom (thickness of ocean)
0.1                                      !dz (discrete step in depth direction)
0                                        !Lb (rigid/free lower boundary condition)
40                                       !tlmin (minimum value of TL in colorbar)
70                                       !tlmax (maximum value of TL in colorbar)
2                                        !n_w (profiles’ points in water column)
2                                        !n_b    (profiles’ points in bottom sediment)
    0.0 1500.0   1.0    0.0              !depw cw rhow alphaw
   50.0 1500.0   1.0    0.0
   50.0 1800.0   1.5    1.5              !depb cb rhob alphab
  100.0 1800.0   1.5    1.5
```

The “input.txt” file include: casename, Nw (the number to truncated order of water column), Nb (the number to truncated order of bottom sediment), Nw and Nb may be equal or unequal. Generally speaking, the more complicated the shape of the sound speed profile, the more Nw and Nb are needed to accurately fit.

cpmax is the maximum phase speed limit, which used to determine how many modes are accumulated in the final synthesized sound field, generally set by the user according to experience (m/s). freq (frequency of source, Hz), zs (the depth of source, m), zr (depth of a special receiver, user used to specify to draw the transmission loss curve of arbitrary depth, m), rmax (the maximum range of horizontal direction, m), dr (horizontal discrete step, m), h (thickness of water column, m), H (thickness of ocean, m), h must less than H, dz (discrete step size in depth direction, m), Lb (User used to specify whether the seabottom boundary condition is perfectly free '0' or perfectly rigid '1'), tlmin and tlmax are the minmum and maximum value transmission loss, respectively, which used to determine the color range of the output transmission loss graph, tlmin must less than tlmax.

n_w and n_b are the amount of environmental profile data in water column and bottom sediment respectively. There are two tables of environmental parameter: one for the water column and one for the bottom sediment, both of their units are depth(m), speed(m/s), density(gm/cm^3) and attenuation (dB/wavelength), with n_w and n_b points in each. It is necessary that depw(n_w)=depb(1) where the density usually has a discontinuity. The first entry depw(1)=0 is the free surface. The last entry depb(nb)=H determines the total thickness of the waveguide. The plots resulting from the above dialog are as follows:

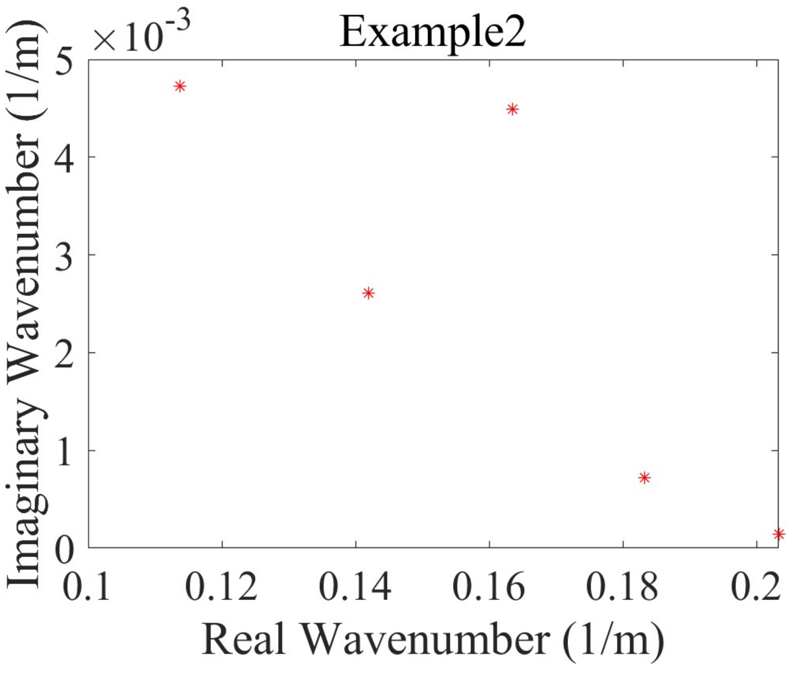

Figure 1. Complex horizontal wavenumbers.

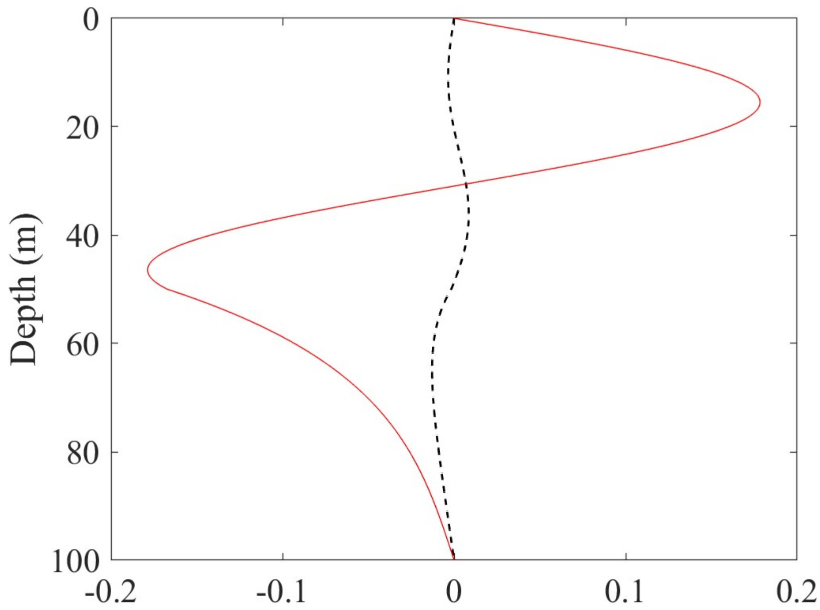

Figure 2. Mode number 2 versus depth.

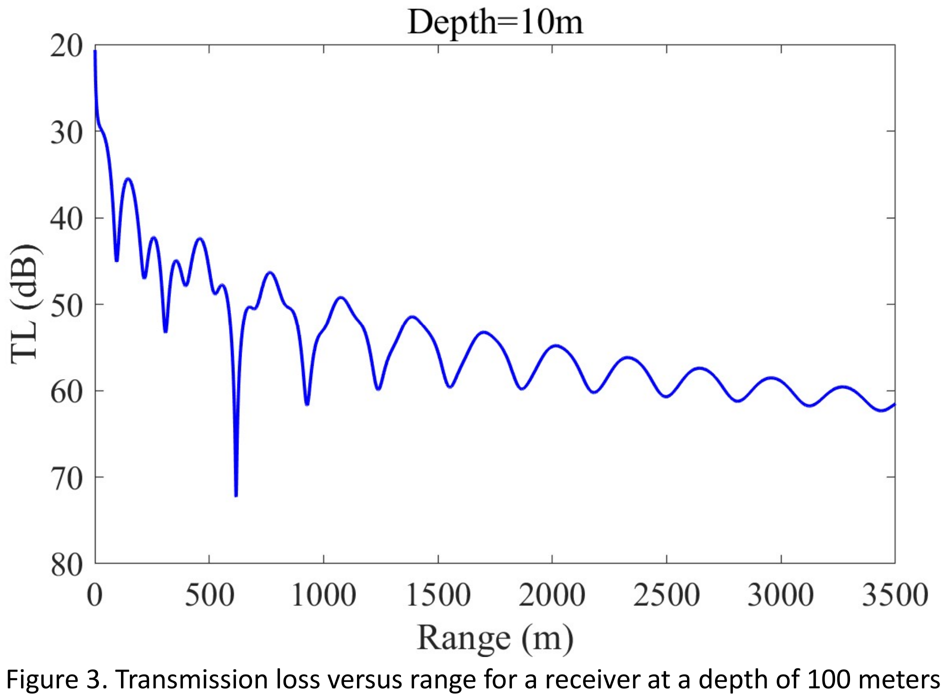

Figure 3. Transmission loss versus range for a receiver at a depth of 100 meters.

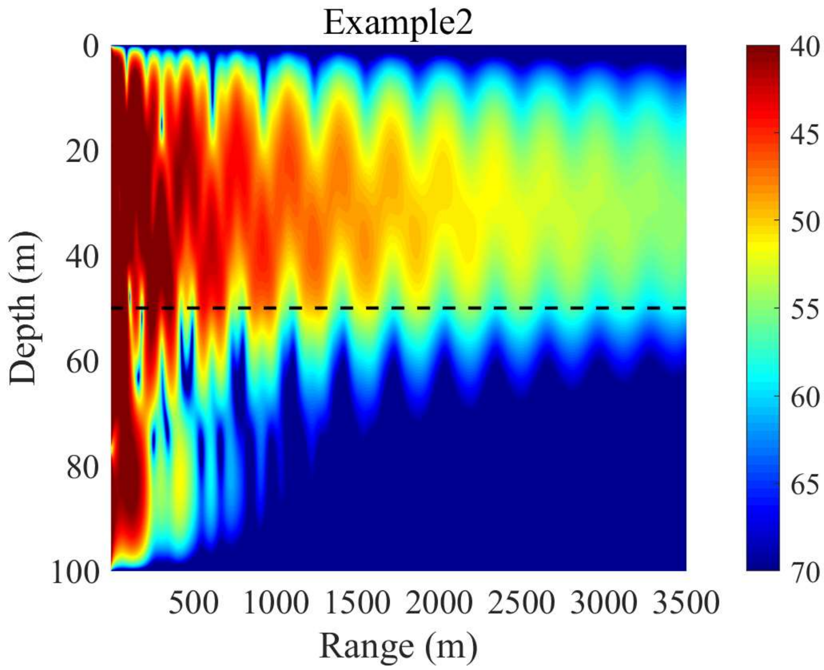

Figure 4. A colorful plot of transmission loss, range versus depth.