MASWaves – User manual

Version 1

July 11, 2017

Preface/disclaimers

This document provides guidelines to use the MASWaves open source software. The software is written in MATLAB. The software and the sample data used in the “quick start guide” can be downloaded free of charge at http://uni.hi.is/eao4/.

The MASWaves software can be used and modified free of charge. The author(s) take no responsibility for the use of the software, and make no guarantees, expressed or implied, about its quality, reliability, or any other characteristic. Users of MASWaves assume sole responsibility for its use in any particular application, for any conclusions drawn from the results of its use, and for any actions taken or not taken as a result of analysis performed using this software.

References

Referencing the MASWaves software and publications related to its development is highly appreciated. Below is a list of publications related to the development of MASWaves.

<u>Development of MASWaves</u>

Olafsdóttir, E.A., Erlingsson, S., & Bessason, B. (2017). Tool for analysis of MASW field data and evaluation of shear wave velocity profiles of soils. *Canadian Geotechnical Journal*. Published on the web 11 July 2017, https://doi.org/10.1139/cgj-2016-0302

<u>Additional references</u>

Olafsdottir, E.A. (2016). *Multichannel Analysis of Surface Waves for Assessing Soil Stiffness*. M.Sc. thesis, Faculty of Civil and Environmental Engineering, University of Iceland, Reykjavík, Iceland. http://hdl.handle.net/1946/23646

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1. Introduction

MASWaves (Multichannel Analysis of Surface Waves for assessing shear wave velocity profiles of soils) is an open source software, developed at the Faculty of Civil and Environmental Engineering, University of Iceland, for processing and analyzing multichannel surface wave records using MASW. The software is written in MATLAB.

MASWaves contains two fundamental parts; a tool for processing of MASW field data and evaluation of experimental dispersion curves (MASWaves Dispersion) and a tool for computation of theoretical dispersion curves and evaluation of shear wave velocity profiles by backcalculation of the experimental data (MASWaves Inversion). An overview of the software is provided in Figure 1.

MASWaves Dispersion consists of the following .m-files. A description of each .m-file and a list of its input and output arguments is provided in sections 3.1 to 3.7.

- *MASWaves_read_data.m*
- *MASWaves_plot_data.m*
- *MASWaves_dispersion_imaging.m*
- *MASWaves_plot_dispersion_image_2D.m*
- *MASWaves_plot_dispersion_image_3D.m*
- *MASWaves_extract_dispersion_curve.m*
- *MASWaves_plot_dispersion_curve.m*

MASWaves Inversion consists of the following .m-files. A description of each .m-file and a list of its input and output arguments is provided in the sections 4.1 to 4.4.

- *MASWaves_Ke_layer.m*
- *MASWaves_Ke_halfspace.m*
- *MASWaves_stiffness_matrix.m*
- *MASWaves_theoretical_dispersion_curve.m*
- *MASWaves_misfit.m*
- *MASWaves_plot_theor_exp_dispersion_curves.m*
- *MASWaves_inversion.m*

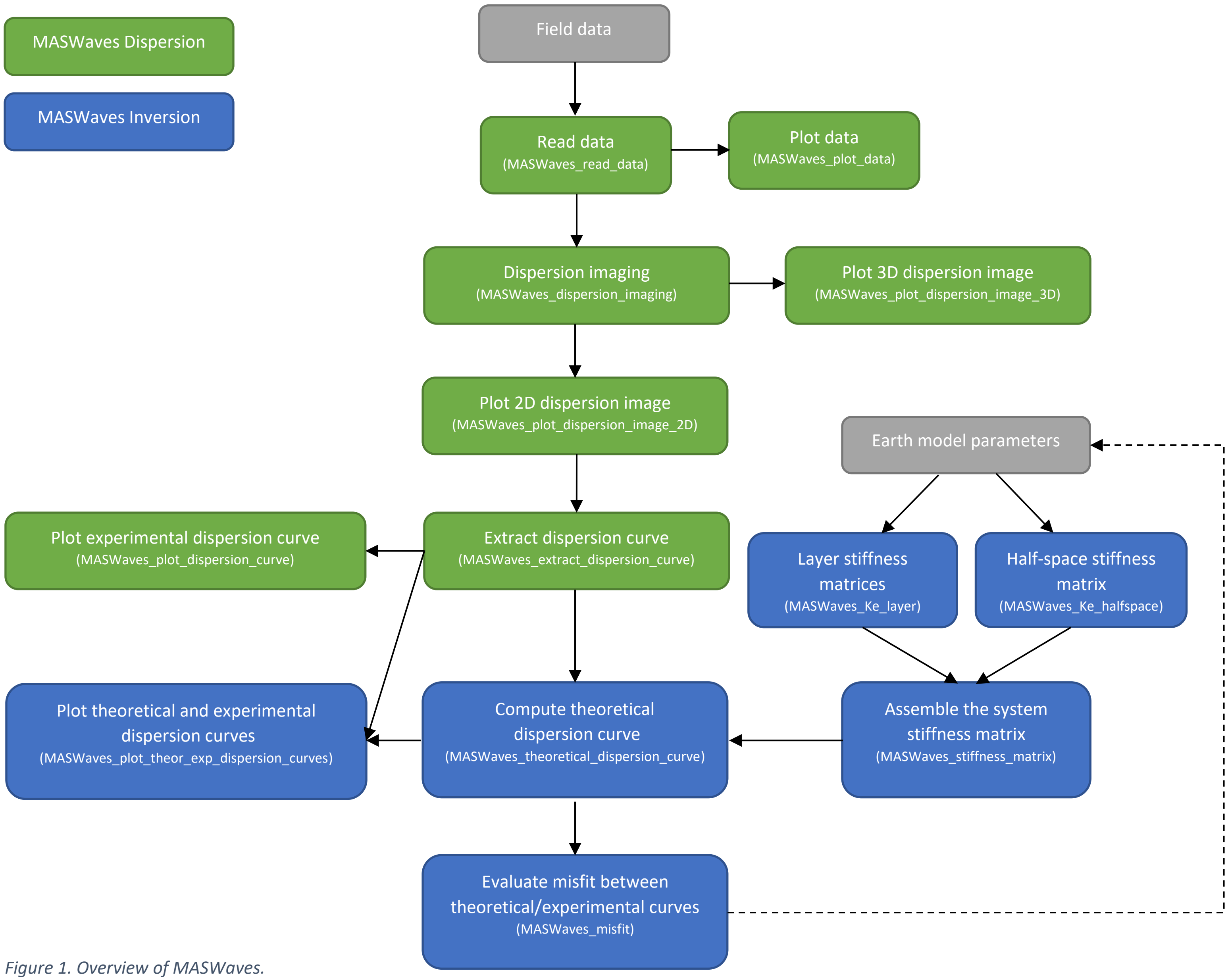

Figure 1. Overview of MASWaves.

2. Quick start guide

- Download the MASWaves software and the sample data (16 files) from http://uni.hi.is/eao4/.
- Import and view the sample data file (SampleData.dat) by using *MASWaves_read_data.m* and *MASWaves_plot_data.m*. A multichannel signal as the one displayed in Figure 2 should appear.
    - The sample data is recorded by using **twenty-four 4.5 Hz** receivers with a receiver spacing (**dx**) of **1 m** and a source offset (**x1**) of **10 m**. The load is applied in **front** of receiver 1. The measuring frequency is **1000 Hz**. The groundwater table is located **at the surface**.

```
Filename = 'SampleData.dat';
HeaderLines = 7;
fs = 1000; % Hz
N = 24;
x1 = 10; % m
dx = 1; % m
Direction = 'forward';
 [u,T,Tmax,L,x] = MASWaves_read_data(Filename,HeaderLines,fs,N,dx,x1,Direction);


du = 1/75;
FigWidth = 7; % cm
FigHeight = 9; % cm
FigFontSize = 8; % pt
figure
MASWaves_plot_data(u,N,dx,x1,L,T,Tmax,du,FigWidth,FigHeight,FigFontSize)
```

- Specify the testing Rayleigh wave velocity range (i.e. the maximum and minimum testing phase velocity values and the testing velocity increment) and carry out the dispersion analysis of the recorded data by using *MASWaves_dispersion_imaging.m*.
- View the dispersion image in two and/or three dimensions by using *MASWaves_plot_dispersion_image_2D.m* and/or *MASWaves_plot_dispersion_image_3D.m*. A two or three dimensional spectra as shown in Figure 3 should be displayed.

```
cT_min = 50; % m/s
cT_max = 400; % m/s
delta_cT = 1; % m/s
[f,c,A] = MASWaves_dispersion_imaging(u,N,x,fs,cT_min,cT_max,delta_cT);


resolution = 100;
fmin = 0; % Hz
fmax = 50; % Hz
FigWidth = 7; % cm
FigHeight = 7; % cm
FigFontSize = 8; % pt
figure
[fplot,cplot,Aplot] = MASWaves_plot_dispersion_image_2D(f,c,A,fmin,fmax,...
    resolution,FigWidth,FigHeight,FigFontSize);

fmin = 1; % Hz
FigWidth = 10; % cm
FigHeight = 10; % cm
figure
[fplot,cplot,Aplot] = MASWaves_plot_dispersion_image_3D(f,c,A,fmin,fmax,...
    FigWidth,FigHeight,FigFontSize);
```

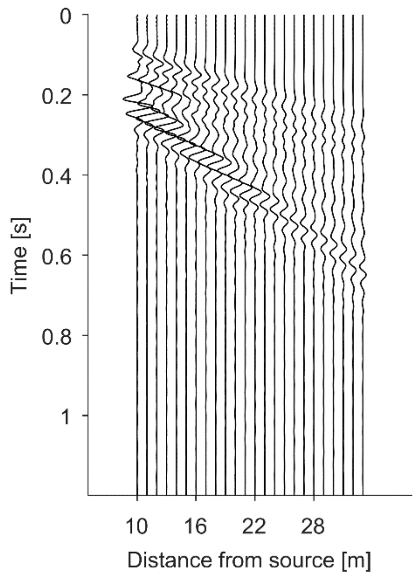

Figure 2. Recorded surface wave data.

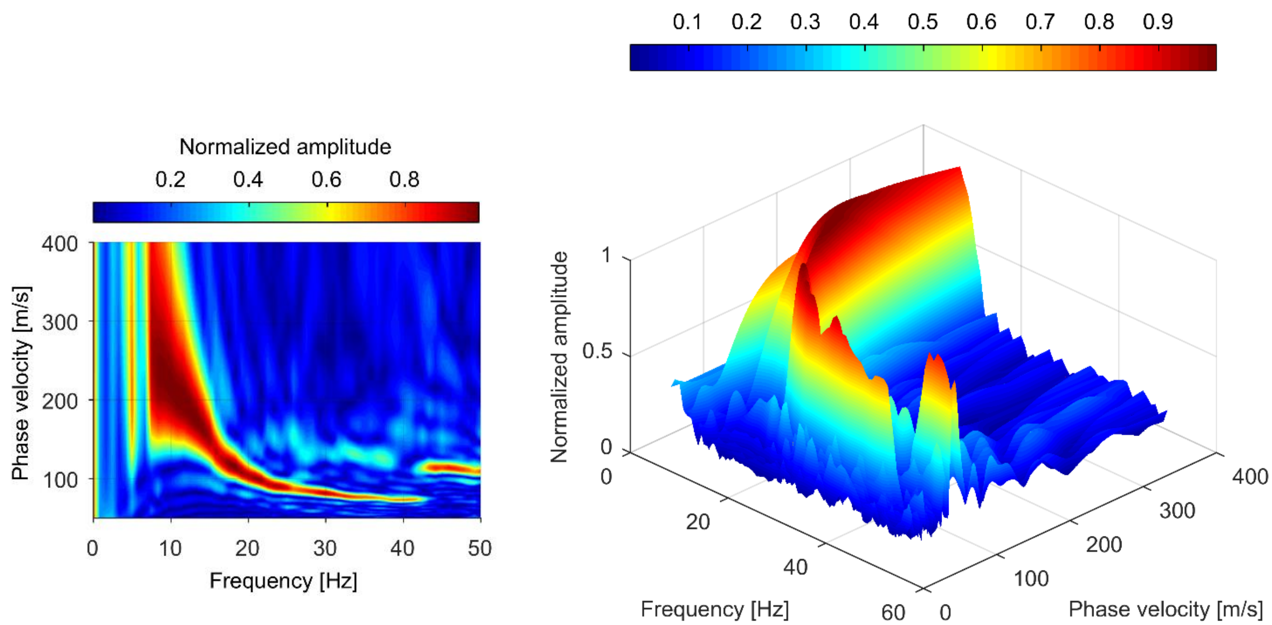

Figure 3. (Left) Two-dimensional dispersion image. (Right) Three-dimensional dispersion image.

- Identify and pick the fundamental mode dispersion curve (with or without upper/lower boundaires) by using *MASWaves_extract_dispersion_curve.m*. It is possible to pick the fundamental mode dispersion curve based on a numbering system (Figure 4) and/or by using the mouse. The numbering system is used in this guide. Here, maxima number 5 to 44 are identified as the fundamental mode.

```
f_receivers = 4.5; % Hz
select = 'numbers';
up_low_boundary = 'yes';
p = 95; % Percentage
[f_curve0,c_curve0,lambda_curve0,...
    f_curve0_up,c_curve0_up,lambda_curve0_up,...
    f_curve0_low,c_curve0_low,lambda_curve0_low] = ...
    MASWaves_extract_dispersion_curve(f,c,A,fmin,fmax,f_receivers,...
    select,up_low_boundary,p);
```

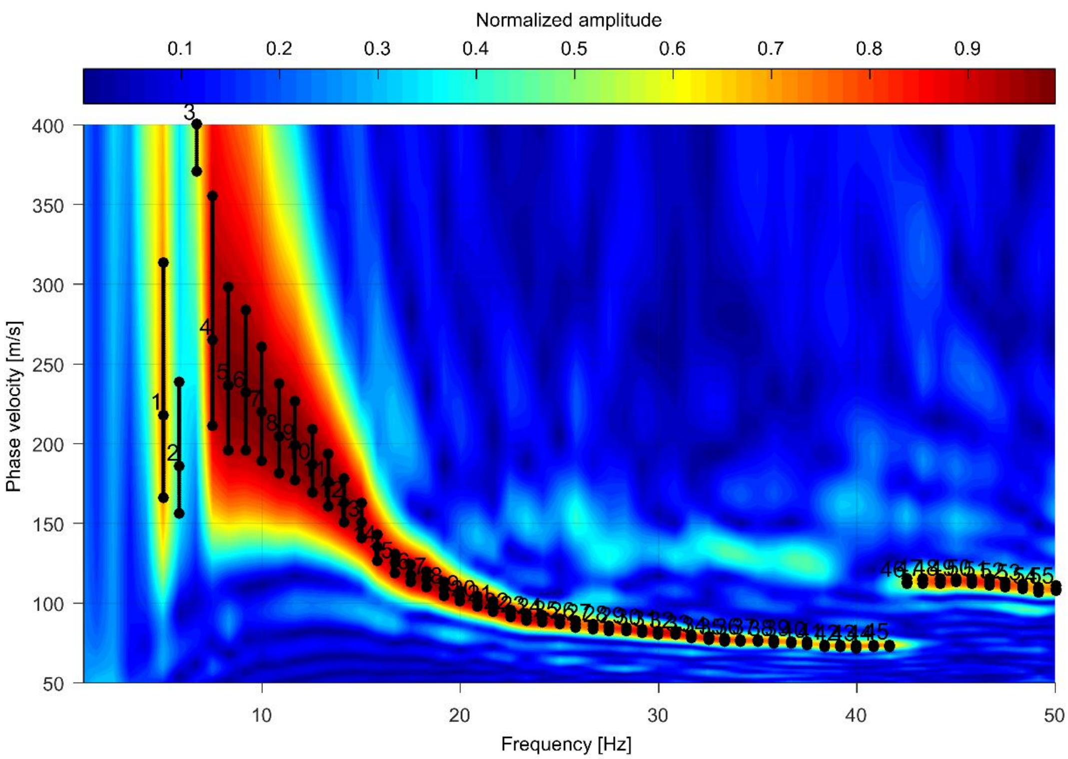

Figure 4. Pick the fundamental mode dispersion curve based on the spectral maxima. Here maxima number 5 to 44 are identified as the fundamental mode.

```
Fundamental mode dispersion curve: [5:44]
```

- View the fundamental mode dispersion curve by using *MASWaves_plot_dispersion_curve.m*. The fundamental mode dispersion curve can either by viewed as frequency vs. Rayleigh wave velocity or as Rayleigh wave velocity vs. wavelength (Figure 5).

```
FigWidth = 9; % cm
FigHeight = 6; % cm
FigFontSize = 8; % pt
type = 'f_c';
up_low_boundary = 'yes';
figure
MASWaves_plot_dispersion_curve(f_curve0,c_curve0,lambda_curve0,...
     f_curve0_up,c_curve0_up,lambda_curve0_up,f_curve0_low,c_curve0_low,...
     lambda_curve0_low,type,up_low_boundary,FigWidth,FigHeight,FigFontSize)


FigWidth = 7; % cm
FigHeight = 9; % cm
FigFontSize = 8; % pt
type = 'c_lambda';
up_low_boundary = 'yes';
figure
MASWaves_plot_dispersion_curve(f_curve0,c_curve0,lambda_curve0,...
     f_curve0_up,c_curve0_up,lambda_curve0_up,f_curve0_low,c_curve0_low,...
     lambda_curve0_low,type,up_low_boundary,FigWidth,FigHeight,FigFontSize)
```

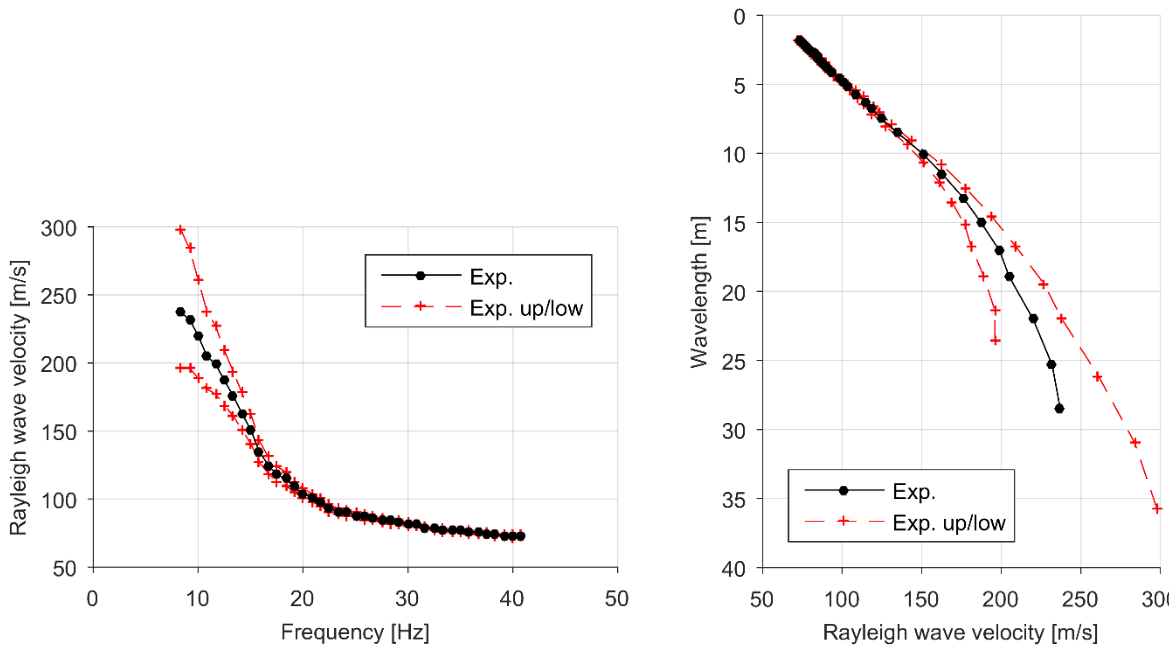

Figure 5. Fundamental mode dispersion curve. (Left) Frequency vs. Rayleigh wave velocity. (Right) Rayleigh wave velocity vs. wavelength.

- Specify a layer model for the inversion analysis. The parameters required to specify the model are number of finite thickness layers (n), layer thickness (h), shear wave velocity (β), mass density (ρ) and compressional wave velocity (α) (or Poisson's ratio (ν)). If the Poisson's ratio of the j-layer is specified, the corresponding compressional wave velocity (which is used as an input parameter) is computed as

$$\nu_j = \frac{\alpha_j^2 - 2\beta_j^2}{2(\alpha_j^2 - \beta_j^2)}$$

- Specify range for the testing Rayleigh wave phase velocity (i.e. specify minimum and maximum values for the testing phase velocity as well as the testing phase velocity increment).
- Compute a theoretical fundamental mode dispersion curve based on the assumed layer model by using *MASWaves_theoretical_dispersion_curve.m*.
- View the theoretical and experimental dispersion curves (Figure 6) by using *MASWaves_plot_theor_exp_dispersion_curves.m*) and evaluate the misfit between the two curves by using *MASWaves_misfit.m*.
- Update the shear wave velocity profile and/or the layer thicknesses until the theoretical dispersion curve becomes sufficiently close to the experimental curve (i.e. the misfit between the two curves has reached an acceptably small value).

```
% Repeated use of MASWaves_theoretical_dispersion_curve.m, MASWaves_misfit.m
% and MASWaves_plot_theor_exp_dispersion_curves.m
% (For iteration, the layer parameters should be updated and this code section run
% again).

c_test_min = 0; % m/s
c_test_max = 500; % m/s
delta_c_test = 0.5; % m/s
c_test = c_test_min:delta_c_test:c_test_max; % m/s


% Layer parameters
n = 6;
alpha = [1440 1440 1440 1440 1440 1440 1440]; % m/s
h = [1 1 2 2 4 5 Inf]; % m
beta = [75 90 150 180 240 290 290]; % m/s
rho = [1850 1850 1850 1850 1850 1850 1850]; % kg/m^3

up_low_boundary = 'yes';
[c_t,lambda_t] = MASWaves_theoretical_dispersion_curve...
    (c_test,lambda_curve0,h,alpha,beta,rho,n);


up_low_boundary = 'yes';
FigWidth = 8; % cm
FigHeight = 10; % cm
FigFontSize = 8; % pt
figure
MASWaves_plot_theor_exp_dispersion_curves(c_t,lambda_t,...
    c_curve0,lambda_curve0,c_curve0_up,lambda_curve0_up,...
    c_curve0_low,lambda_curve0_low,up_low_boundary,...
    FigWidth,FigHeight,FigFontSize)


e = MASWaves_misfit(c_t,c_curve0);
```

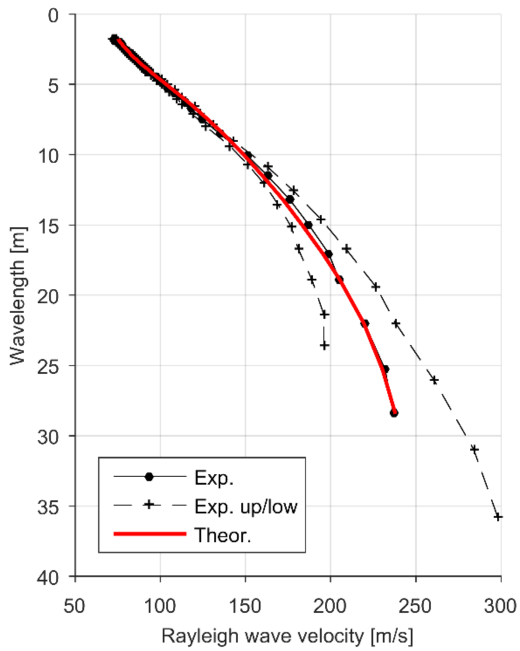

Figure 6. Comparison of theoretical and experimental fundamental mode dispersion curves.

- Instead of repeated use of *MASWaves_theoretical_dispersion_curve.m*, *MASWaves_misfit.m* and *MASWaves_plot_theor_exp_dispersion_curves.m*, the analyst can carry out the inversion analysis through *MASWaves_inversion.m* (which has *MASWaves_theoretical_dispersion_curve.m*, *MASWaves_misfit.m* and *MASWaves_plot_theor_exp_dispersion_curves.m* as subroutines) and follow the prompts in the Command Window.

```
% Use of MASWaves_inversion
c_test_min = 0; % m/s
c_test_max = 500; % m/s
delta_c_test = 0.5; % m/s
c_test = c_test_min:delta_c_test:c_test_max; % m/s

% Layer parameters
n = 6;
alpha = [1440 1440 1440 1440 1440 1440 1440]; % m/s
h = [1 1 2 2 4 5 Inf]; % m
beta = [75 90 150 180 240 290 290]; % m/s
rho = [1850 1850 1850 1850 1850 1850 1850]; % kg/m^3
up_low_boundary = 'yes';
[c_t,lambda_t,e] = MASWaves_inversion(c_test,h,alpha,beta,rho,n,...
    up_low_boundary,c_curve0,lambda_curve0,c_curve0_up,lambda_curve0_up,...
    c_curve0_low,lambda_curve0_low);

% View the results
up_low_boundary = 'yes';
FigWidth = 8; % cm
FigHeight = 10; % cm
FigFontSize = 8; % pt
figure
MASWaves_plot_theor_exp_dispersion_curves(c_t,lambda_t,...
    c_curve0,lambda_curve0,c_curve0_up,lambda_curve0_up,...
    c_curve0_low,lambda_curve0_low,up_low_boundary,...
    FigWidth,FigHeight,FigFontSize)
```

3. MASWaves Dispersion

3.1 Read data (MASWaves_read_data)

The function MASWaves_read_data loads recorded surface wave data into MATLAB and determines the length of the receiver spread, the location of individual receivers and the total recording time.

Input arguments

Filename	Path of file where recorded data is stored [string] - Recorded data should be stored in an ASCII-delimited text file. - Each recorded surface wave trace should be stored in a single column.
HeaderLines	Number of header lines
fs	Measuring frequency [Hz]
N	Number of receivers
dx	Receiver spacing [m]
x1	Source offset [m]
Direction	'forward' or 'backward' [string] - 'forward': Forward measurement. Source is applied next to receiver 1. - 'backward': Backward measurement. Source is applied next to receiver N.

Output arguments

u	u(x,t) offset-time shot gather
T	Time of individual recordings [s]
Tmax	Total recording time [s]
L	Length of receiver spread [m]
x	Location of receivers, distance from seismic source [m]

3.2 Plot data (MASWaves_plot_data)

The function MASWaves_plot_data plots recorded multichannel surface wave data in the offset-time domain.

Input arguments

u	u(x,t) offset-time shot gather
N	Number of receivers
dx	Receiver spacing [m]
x1	Source offset [m]
L	Length of receiver spread [m]
T	Time of individual recordings [s]
Tmax	Total recording time [s]
du	Scale factor for offset between traces
FigWidth	Width of figure [cm]
FigHeight	Height of figure [cm]
FigFontSize	Font size for axis labels [pt]

3.3. Dispersion imaging (MASWaves_dispersion_imaging)

The function MASWaves_dispersion_imaging carries out the first three steps of the dispersion analysis of the recorded surface wave data. The analysis is carried out using the phase-shift method.

Input arguments

u	u(x,t) offset-time shot gather
N	Number of receivers
x	Location of receivers, distance from seismic source [m]
fs	Recording frequency [Hz]
cT_min	Testing Rayleigh wave phase velocity (minimum value) [m/s]
cT_max	Testing Rayleigh wave phase velocity (maximum value) [m/s]
delta_cT	Testing Rayleigh wave phase velocity increment [m/s]

Output arguments

f	Frequency [Hz]
c	Rayleigh wave velocity [m/s]
A	Summed (slant-stacked) amplitude corresponding to different combinations of omega=2*pi*f and cT

3.4 Plot two-dimensional dispersion image (MASWaves_plot_dispersion_image_2D)

The function MASWaves_plot_dispersion_image_2D plots the two-dimensional dispersion image of the recorded wavefield. The slant-stacked amplitude (A) is presented in the frequency - phase velocity - normalized summed amplitude domain using a color scale.

MASWaves_plot_dispersion_image_2D plots the dispersion image between the limits [f_min, f_max, cT_min, cT_max].

Input arguments

f	Frequency [Hz]
c	Rayleigh wave velocity [m/s]
A	Summed (slant-stacked) amplitude corresponding to different combinations of omega=2*pi*f and cT
fmin	Lower limit of the frequency axis [Hz]
fmax	Upper limit of the frequency axis [Hz]
resolution	Number of contour lines - resolution = 100 is generally recommended
FigWidth	Width of figure [cm]
FigHeight	Height of figure [cm]
FigFontSize	Font size for axis labels [pt]

Output arguments

fplot	Frequency range of the dispersion image [Hz]
cplot	Velocity range of the dispersion image [m/s]
Aplot	Summed (slant-stacked) amplitude corresponding to fplot and cplot

3.5 Plot three-dimensional dispersion image (MASWaves_plot_dispersion_image_3D)

The function MASWaves_plot_dispersion_image_3D plots the three-dimensional dispersion image of the recorded wavefield. The slant-stacked amplitude (A) is presented in the frequency - phase velocity - normalized summed amplitude domain.

MASWaves_plot_dispersion_image_3D plots the dispersion image between the limits [f_min, f_max, cT_min, cT_max].

Input arguments

f	Frequency [Hz]
c	Rayleigh wave velocity [m/s]
A	Summed (slant-stacked) amplitude corresponding to different combinations of omega=2*pi*f and cT
fmin	Lower limit of the frequency axis [Hz]
fmax	Upper limit of the frequency axis [Hz]
FigWidth	Width of figure [cm]
FigHeight	Height of figure [cm]
FigFontSize	Font size for axis labels [pt]

Output arguments

fplot	Frequency range of the dispersion image [Hz]
cplot	Velocity range of the dispersion image [m/s]
Aplot	Summed (slant-stacked) amplitude corresponding to fplot and cplot

3.6 Extract experimental fundamental mode dispersion curve (MASWaves_extract_dispersion_curve)

The function MASWaves_extract_dispersion_curve is used to identify and extract the fundamental mode dispersion curve based on the 2D dispersion image. The fundamental mode dispersion curves is identified manually based on the spectral maxima observed at each frequency (using a numbering system). Additionally, upper and lower boundaries for the fundamental mode dispersion curve, corresponding to p% of the identified fundamental mode peak spectral amplitude value at each frequency, can be obtained. Additional points can be added to the fundamental mode dispersion curve (and the upper/lower bound curves) by using the mouse.

Alternatively, the fundamental mode dispersion curve, along with upper/lower boundaries, can be selected entirely by using the mouse.

Input arguments

f	Frequency [Hz]
c	Rayleigh wave velocity [m/s]
A	Summed (slant-stacked) amplitude corresponding to different combinations of omega=2*pi*f and cT
fmin	Lower limit of the frequency axis [Hz]
fmax	Upper limit of the frequency axis [Hz]
f_receivers	Eigenfrequency of receivers (geophones) [Hz]
select	Controls how the fundamental mode dispersion curve is selected based on the dispersion image - 'mouse' Points selected by mouse clicking. - 'numbers' Points selected based on a numbering system. - 'both' Points selected based on a numbering system. Additional points can be selected by mouse clicking.
up_low_boundaries	- 'yes' Upper/lower boundaries for the fundamental mode dispersion curve are wanted. - 'no' Upper/lower boundaries for the fundamental mode dispersion curve are not wanted.
p	Percentage value for determination of upper/lower bound curves [%]

Output arguments

f_curve0	Frequency [Hz]
c_curve0	Rayleigh wave velocity [m/s]
lambda_curve0	Wavelength [m]
f_curve0_up	Frequency, upper bound curve [Hz] f_curve0_up = [ ] if upper/lower boundaries are not wanted
c_curve0_up	Rayleigh wave velocity, upper bound curve [m/s] c_curve0_up = [ ] if upper/lower boundaries are not wanted
lambda_curve0_up	Wavelength, upper bound curve [m] lambda_curve0_up = [ ] if upper/lower boundaries are not wanted
f_curve0_low	Frequency, lower bound curve [Hz] f_curve0_low = [ ] if upper/lower boundaries are not wanted
c_curve0_low	Rayleigh wave velocity, lower bound curve [m/s] c_curve0_low = [ ] if upper/lower boundaries are not wanted
lambda_curve0_low	Wavelength, lower bound curve [m] lambda_curve0_low = [ ] if upper/lower boundaries are not wanted

3.7 Plot dispersion curve (MASWaves_plot_dispersion_curve)

The function MASWaves_plot_dispersion_curve is used to plot the fundamental mode dispersion curve, with or without upper/lower boundaries. The dispersion curve is either presented as frequency vs. Rayleigh wave velocity or as Rayleigh wave velocity vs. wavelength.

Input arguments

f_curve0	Frequency [Hz]
c_curve0	Rayleigh wave velocity [m/s]
lambda_curve0	Wavelength [m]
f_curve0_up	Frequency, upper bound curve [Hz] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
c_curve0_up	Rayleigh wave velocity, upper bound curve [m/s] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
lambda_curve0_up	Wavelength, upper bound curve [m] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
f_curve0_low	Frequency, lower bound curve [Hz] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
c_curve0_low	Rayleigh wave velocity, lower bound curve [m/s] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
lambda_curve0_low	Wavelength, lower bound curve [m] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
type	Controls how the dispersion curve is presented - 'f_c' Frequency vs. Rayleigh wave velocity - 'c_lambda' Rayleigh wave velocity vs. wavelength
up_low_boundaries	- 'yes' Upper/lower boundaries for the fundamental mode dispersion curve are wanted. - 'no' Upper/lower boundaries for the fundamental mode dispersion curve are not wanted.
FigWidth	Width of figure [cm]
FigHeight	Height of figure [cm]
FigFontSize	Font size for axis labels [pt]

4. MASWaves Inversion

4.1 Compute theoretical fundamental mode dispersion curve (MASWaves_theoretical_dispersion_curve)

The function MASWaves_theoretical_dispersion_curve computes the theoretical fundamental mode dispersion curve for the layer model defined by h, alpha, beta, rho and n at wavelengths lambda.

Input arguments

c_test	Testing Rayleigh wave velocity vector [m/s]
lambda	Wavelength vector [m]
h	Layer thicknesses [m] (vector of length n)
alpha	Compressional wave velocity [m/s] (vector of length n+1)
beta	Shear wave velocity [m/s] (vector of length n+1)
rho	Mass density [kg/m^3] (vector of length n+1)
n	Number of finite thickness layers

Output arguments

c_t	Rayleigh wave velocity vector (theoretical fundamental mode dispersion curve) [m/s]
lambda_t	Rayleigh wave wavelength (theoretical fundamental mode dispersion curve) [m]

4.1.1. Compute layer stiffness matrices for finite thickness layers (MASWaves_Ke_layer)

The function MASWaves_Ke_layer computes the element stiffness matrix of the j-th layer (j = 1,...,n) of the stratified earth model that is used in the inversion analysis.

Input arguments

h	Layer thickness [m]
alpha	Compressional wave velocity [m/s]
beta	Shear wave velocity [m/s]
rho	Mass density [kg/m^3]
c_test	Testing Rayleigh wave velocity [m/s]
k	Wave number

Output argument

Ke	Element stiffness matrix of the j-th layer

4.1.2 Compute half-space stiffness matrix (MASWaves_Ke_halfspace)

The function MASWaves_Ke_halfspace computes the element stiffness matrix for the half-space (layer n+1) of the stratified earth model that is used in the inversion analysis.

Input arguments

alpha	Half-space compressional wave velocity [m/s]
beta	Half-space shear wave velocity [m/s]
rho	Half-space mass density [kg/m^3]
c_test	Testing Rayleigh wave velocity [m/s]
k	Wave number

Output argument

Ke_halfspace	Half-space element stiffness matrix

4.1.3 Assemble system stiffness matrix (MASWaves_stiffness_matrix)

The function MASWaves_stiffness_matrix assembles the system stiffness matrix of the stratified earth model that is used in the inversion analysis and computes its determinant.

Input arguments

c_test	Testing Rayleigh wave velocity [m/s]
k	Wave number
h	Layer thicknesses [m] (vector of length n)
alpha	Compressional wave velocity [m/s] (vector of length n+1)
beta	Shear wave velocity [m/s] (vector of length n+1)
rho	Mass density [kg/m^3] (vector of length n+1)
n	Number of finite thickness layers

Output argument

D	Determinant of the system stiffness matrix

4.2 Plot theoretical and experimental fundamental mode dispersion curves (MASWaves_plot_theor_exp_dispersion_curves)

The function MASWaves_plot_theor_exp_dispersion_curves is used to plot the theoretical and experimental fundamental mode dispersion curves, with or without the upper/lower experimental boundaries. The dispersion curve is presented as Rayleigh wave phase velocity vs. wavelength.

Input arguments

c_t	Rayleigh wave velocity vector (theoretical fundamental mode dispersion curve) [m/s]
lambda_t	Rayleigh wave wavelength (theoretical fundamental mode dispersion curve) [m]
c_curve0	Rayleigh wave velocity (experimental fundamental mode dispersion curve) [m/s]
lambda_curve0	Wavelength (experimental fundamental mode dispersion curve) [m]
c_curve0_up	Rayleigh wave velocity, upper bound curve (experimental curve) [m/s] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
lambda_curve0_up	Wavelength, upper bound curve (experimental curve) [m] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
c_curve0_low	Rayleigh wave velocity, lower bound curve (experimental curve) [m/s] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
lambda_curve0_low	Wavelength, lower bound curve (experimental curve) [m] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
up_low_boundaries	- 'yes' Upper/lower boundaries for the experimental fundamental mode dispersion curve are wanted. - 'no' Upper/lower boundaries for the experimental fundamental mode dispersion curve are not wanted.
FigWidth	Width of figure [cm]
FigHeight	Height of figure [cm]
FigFontSize	Font size for axis labels [pt]

4.3 Evaluate misfit between theoretical/experimental curves (MASWaves_misfit)

The function MASWaves_misfit is used to evaluate the misfit between the theoretical and experimental fundamental mode dispersion curves. The theoretical and experimental curves are assumed to have been evaluated at the same wavelengths.

Input arguments

c_t	Rayleigh wave velocity vector (theoretical fundamental mode dispersion curve) [m/s]
c_curve0	Rayleigh wave velocity vector (experimental fundamental mode dispersion curve) [m/s]

Output argument

e	Misfit [%]

4.4 Carry out the inversion analysis using a single .m file (MASWaves_inversion)

The function MASWaves_inversion can be used to carry out the inversion analysis through a single .m file (manual inversion). The function (1) computes the theoretical fundamental mode dispersion curve for the layer model defined by h, alpha, beta, rho and n at the same wavelengths as are included in the experimental curve, (2) plots the theoretical and experimental curves and (3) evaluates the misfit between the theoretical and experimental curves. For each iteration, the function MASWaves_inversion allows the user to choose between saving the theoretical dispersion curve obtained in the current iteration (in a text file), to stop without saving or to iterate again.

Input arguments

c_test	Testing Rayleigh wave velocity vector [m/s]
h	Layer thicknesses [m] (vector of length n)
alpha	Compressional wave velocity [m/s] (vector of length n+1)
beta	Shear wave velocity [m/s] (vector of length n+1)
rho	Mass density [kg/m^3] (vector of length n+1)
n	Number of finite thickness layers
up_low_boundaries	- 'yes' Upper/lower boundaries for the experimental fundamental mode dispersion curve are wanted. - 'no' Upper/lower boundaries for the experimental fundamental mode dispersion curve are not wanted.
c_curve0	Rayleigh wave velocity (experimental fundamental mode dispersion curve) [m/s]
lambda_curve0	Wavelength (experimental fundamental mode dispersion curve) [m]
c_curve0_up	Rayleigh wave velocity, upper bound curve (experimental dispersion curve) [m/s] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
lambda_curve0_up	Wavelength, upper bound curve (experimental dispersion curve) [m] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
c_curve0_low	Rayleigh wave velocity, lower bound curve (experimental dispersion curve) [m/s] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)
lambda_curve0_low	Wavelength, lower bound curve (experimental dispersion curve) [m] (Can be assigned as 'nan' or [ ] if upper/lower boundaries are not wanted.)

Output arguments

c_t	Rayleigh wave velocity vector (theoretical fundamental mode dispersion curve) [m/s]
lambda_t	Rayleigh wave wavelength (theoretical fundamental mode dispersion curve) [m]
e	Misfit [%]