Integrated Landslide and Tsunami simulation software LS-Tsunami

Instruction manual

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1. Introduction

This chapter shows how to use Integrated Landslide-Tsunami simulation model (LS-Tsunami). If this part can be clearly understood, simulations can be conducted successfully. Common operations with Landslide simulation (LS-RAPID) are shown in its operation manual.

1-1. About this software

This LS-Tsunami software is designed to couple two computing simulations: the landslide simulation (LS-RAPID) and the tsunami computing simulation produced under the editorship of Kyoji Sassa (International Consortium on Landslides) and Hideaki Yanagisawa (Tohoku Gakuin University). This software can run on a Windows PC. The software has visual interfaces and produces 3D graphical computational results to help beginners to carry out an integrated landslide and tsunami simulation.

• OS	Windows 7, Windows 8, Windows10			
• Hardware	Computers supported with above OSs and a multicore CPU (ex. Intel			
	Core2Duo) is required.			
• Memory	More than 2 GB is recommended			
• HDD	More than 1 GB of free space is required			
• Drive	CD-ROM drive to install the software			
• Display	More than 1280 x 800			
Mouse device	Mouse with wheel is required			
• GPU	nVIDIA (GeForce series) or ATI Technologies (RADEON series) is			
	recommended. Other GPUs may not work properly.			
• Software	Landslide computing simulation, LS-RAPID Version 2.12 or newer			
	version			

1-2. System requirements

■ About a display error due to a GPU mismatch

If a screen display very slowly when you do not use above recommended GPUs, click [Display properties] - [Configurations] - [Details] - [Troubleshooting], and set "No" for Hardware Accelerator.

1-3. Installation

This chapter shows how to install LS-Tsunami. When you insert the CD-ROM and start to install the program, the installation window automatically appears.

Click "Next" to start the installation.



If you install the program on a drive other than C, choose another drive in the next window and click "Next" to proceed.



This window shows the group folder of LS-RAPID and LS-Tsunami software in the start menu. Click "Next" to proceeds in the next window.

Select Program Manager	r Group	×
	Enter the name of the Program Manager group to add LS-Tsunami (English) Version1 icons to:	•
		-
	< Back	əl

Click "Next" to start installation.



When the next window appears, installation is done. Click "Finish >" to finish the installation and close the window.



You need to install a "protector driver", if you are not a user of the trial version and if you have already installed it. Details are in "manual/guide.pdf" in the CD-ROM.

To use the LS-Tsunami, you have to obtain the optional license code with LS-RAPID. Details are in "manual/licence.pdf" in the CD-ROM.

1-4. Starting up

For starting up, click [START] – [Show all programs] – [ICL] – [LS-Tsunami].

You will get to the next start window that shown below. Then click the 'start' button for the operational window.



2. Functions of this program

You can use two types of computing simulation with this program.

1) Landslide + Tsunami simulation

First the landslide simulation is carried out by LS-RAPID and then the tsunami simulation is carried out using those results. (Chapter. 3)

2) Tsunami simulation

Normal tsunami computing simulation that using crust deformation parameters. (Chapter. 4)





When the next window appears, you select the type of simulation you need and then click OK. The left window shows the integrated landslide - tsunami simulation, and the right window shows a normal tsunami simulation.



3. Landslide + Tsunami simulation

3-1. Simulation Steps

Figure below shows the flow diagram to carry out the LS-RAPID and LS-Tsunami simulation.



3-2. Setting of simulation area

Click flow [1: Mesh] – [Simulation area], or menu [Edit] - [Setting simulation area and data editing], and input the area of calculation. Setting procedure is similar to LS-RAPID.

3: Simulation Interster control point data to mesh data (C) Setting of simulation area Axial setting of simulation area X-direction Min = 0.000 Max = 500.000 (m) X direction Min = 0.000 Max = 500.000 (m)	fit(E) View(O) Parameters(P) Execute(C) Help(H) Setting simulation area and data editing (P) Editing of Control Point Transfer control point data to mech data (C)	ow Mesh Select analyze method Simulation area Editing of mesh Calculation condition
Setting of simulation area Axial setting of simulation area X-direction Min = 0.000 Max = 500.000 (m)	Transfer control point data to mesh data (C)	Simulation
Axial setting of simulation area X-direction Min = 0.000 Max = 500.000 (m)	input-data type	Setting of simulation area and
X-direction Min = 0.000 Max = 500.000 (m)		Axial setting of simulation area
V direction Min - 0.000 May - 500.000 ()	Max = 500.000 (m)	X-direction Min = 0.00
T-urecuon Min = 0.000 Max = 300.000 (m)	Max = 500.000 (m)	Y-direction Min = 0.00
Mesh setting of simulation area		Mesh setting of simulation area
(Pitch) (Numbers)	(Numbers)	(Pitch)
X-direction 10.000 (m) X-direction 50	X-direction 50	X-direction 10.000 (m)
Y-direction 10.000 (m) Y-direction 50	Y-direction 50	Y-direction 10.000 (m)
	OK Cancel	0,0

3-3. Editing topographic data

Click Flow [1: Mesh] – [Editing of mesh] for opening the window to input topographic data.

Flow	Ec	diting of mea	h													
1: Mesh		Change head Index	er © F	osition										Po	olygon area	
Select analyze method		Slope Surface	Elevation	Manning	coefficient]							0.0	Set in se	lected rec	tangle
		Mesh[X] [Y]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
		1	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	71 =
		2	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	71
Simulation area		3	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	71
		4	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	71
		5	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	71
		6	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	-/1
		/	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	- 1
Editing of mesh		8	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	7
-		9	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	7
		11	0.007	620.0	0.007	0.007	0.007	0.007	0.007	0.007	0.007	620.0	620.0	620.0	620.0	6
		12	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	5
		13	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	4
		14	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	4:
		15	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	3!
		16	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	21
_		17	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	2
· · · · · · · · · · · · · · · · · · ·		18	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	1. *
2: Calculation condition		< <u> </u>														4
3: Simulation																Close

If there are some random elevation data other than meshed data, use the function [Transfer control point data to mesh data] to produce meshed data values.

Ed	it(<u>E)</u> V	iew(<u>O</u>) Pa	arameters(<u>P)</u> Execi	ute(<u>C</u>)	Help(<u>H</u>)
	Settin	ig simulatio	on area and	data edit	ting (P)	
	Editin	g of Contro	l Point			
	Trans	fer control	point data	to mesh o	lata (C)
Edi	ting of Cont Slope Surface	rol Point Elevation				
	No.	х	Y	Elev. ZG	^	
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					
	11				-	
	12				-	
	13					
	14					

Making topographic data for simulation using LS-Tsunami is similar to the LS-RAPID. Please refer to Chapter 3 in the manual of LS-RAPID.

3-4. Reading of a landslide result (LS-RAPID data file)

Click Flow [2: Calculation condition] – [Select landslide result] is to combine the topographic data for the landslide simulation and the data for tsunami simulation. Click 🗈 in the dialogue box to show how to combine both data.



Click folder to open the data file of LS-RAPID (the calculation result from LS-RAPID).



The next window shows the landslide simulation area on the tsunami simulation area.



Emplace the landslide simulation area on the tsunami simulation area by mouse operation.

Click **?** to show how to operate this command.



Then click [OK] to load the result of the landslide simulation. The following box will appear.



Notice: The landslide simulation using LS-RAPID should be carried out before doing the LS-Tsunami simulation. Therefore, the following 3 settings must be accomplished:

1. Tick the [Calculate submergence] option and set its parameters

Flow		
1: Mesh	Set condition for calculation (Landslide)	
2: Calculation condition	Condition of simulation Motion simulation	Method to give a graph of seismic coefficient Time to start 10.0 (sec)
Soil parameters	Fullmode simulation (initiation + Motion + Expansion) Normal simulation Seismic simulation Rainfall simulation Edition of rainfall	Static Ocyclic @ Seismic Edition of seismic waveform Static / Oyclic parameter settine Horizontal seismic coefficient (Kh) Directional coefficient X-direction coefficient Kx = 0.000 Y-direction coefficient Ky = 0.000 Horizontal coefficient Kh = 0.000
Conditions for calculation	Method to give a graph of pore pressure ratio (nu) Time to start 0.0 (sec) © Static I Fluctuate a value Min = 0.00 Duration = 9999.9 (sec) Max = 0.22 Max Time = 5.0 (sec)	Seismic direction $\theta_{0} = 0.00$ (deg) Vertical seismic coefficient (Ky) Vertical coefficient Kv = 0.000 Substitute the direction of landslide profile
Setting time step	Survey Edition of ru Parameters of condition for strength reduction Source area (by travel length) From (DL) 10 To (DU) 200 (mm)	Frequency / MaxTime / Duration ☐ Fluctuate a value Duration = 60.0 (sec) Hz = 0.00 Max Time = 60.0 (sec) Total Cycle (N) = 10
Setting other conditions	Except source area (by depth of mass) $\Delta hcr = 2.00 \text{ (m)}$ Sating of the submergence cabulation \boxed{V} Calculate submergence Level of the water surface 0 (m) Unit weight of water (γ w) 10.100 (kAV/m3)	Kmax Cycle (N) = 10 Seismic parameter setting Kx max = 0.346 EW Acc(ea0/980 × 0.500 (times)) Ky max = 0.877 NS Acc(ea0/980 × 0.500 (times)) Kv max = 0.500 (times) Kv max = 0.114 UD Acc(ea0/980 × 0.500 (times)) 0.500 (times)
3: Simulation	Graph preview	Set Parameters Cancel

Setting on the LS-RAPID application

2. Set the [Level of the water surface] to conform with the tsunami simulation

Flow		
1: Mesh	Set condition for calculation (Landslide)	Method to give a graph of seismic coefficient
2: Calculation condition	Motion simulation	Time to start 10.0 (sec) Static Ocyclic O Seismic Edition of seismic waveform
Soil parameters	Fullmode simulation (initiation + Motion + Expansion) Normal simulation Seismic simulation Rainfall simulation Edition of rainfall	Static / Cycolic parameter setting Horizontal seismic coefficient (Kh) Directional coefficient X-direction coefficient Kx = 0.000 Y-direction coefficient Ky = 0.000 Horizontal coefficient Kh = 0.000
Conditions for calculation	Method to give a graph of pore pressure ratio (ru) Time to start 0.0 (sec) Static V Fluctuate a value Min = 0.00 Duration = 9999.9 (sec) Max = 0.22 Max Time = 5.0 (sec)	$\label{eq:seismic direction} \begin{array}{l} \text{Seismic direction} \theta = & \hline 0 0 0 \mbox{ (deg)} \\ \hline \hline & \hline &$
Setting time step	Survey Edition of ru Parameters of condition for strength reduction	Frequency / MaxTime / Duration Fluctuate a value Duration = 600 (sec) Hz = 0.000 Max Time = 600 (sec) Total Cycle (N) = 10
Setting other conditions	Except source area (by depth of mass) $\Delta hcr = 2.00$ (m) Setting of the submergence calculation Calculate submergence Level of the water surface 0 (m) Unit weight of water (γ w) 10.100 (kNV/m3)	Kmax Cycle (N) = 10 Seismic parameter setting
3: Simulation	Graph preview	Set Parameters Cancel

Setting on the LS-RAPID application

Identical altitude

Setting on the LS-Tsunami application

🔗 Integrated Land	dslide-Tsunami Simulation Model (LS-Tsunami) 📿 Identical altitu	de
File(<u>F</u>) Edit(<u>E</u>)	View <u>(Q)</u> Parameters(<u>P)</u> Execute(<u>C</u>) Help(<u>H</u>	
🗅 🖻 🖬 🔳	🗞 🗞 🗹 🔚 🛋 🛶 fx 🗗 🚧 🚧 📈	
Setting for topography color		
Default (Pattern A) Default (Pattern A)	attern B)	
Color of topography	Color of horizontamane	
Тор 🕨 1.000	Altitude of plane 0 (m)	
0.850	Color Transparency 30 (%) Position (m) Quantity (%) X 30000 Ambient 30	
0.700	Mixture of plane and topography (DST_COLOR) Y 28050 Transparency of plane (SRC_ALPHA) Z 50000	
0.550		
Middle 0.400	Color Contrast of Contour Color of water surface Contour Interval 100.0 (m) Color Level (m) Indination Emphasis	
0.300	(Emphasis) every 5 High 5.00 1 (Times)	
0.200	Horizontal	
0.010	Drawing thick of contour 2.0 Low -5.00 Harmonize color	
Bottom 0.000	Other coloring factors	
Harmonize Top-Bottom	Choice area line	
Harmonize	3D-View background	
Top-Middle-Bottom	OK Cancel	

3. Tick the [Output the altitude calculation result data] option

Flow	Output setting	
1: Mesh	Calculation step numbers (for result saving) Maximum step 1500000	Output options Assign the head words for output files
2: Calculation condition 3: Simulation	Drawing interval 000 By calc step	Step range to output calculation result
Set calculation output	display Umax, Vmax Minimum time for simulation 200.0 (sec) Output of altitude information Output the altitude calculation result data No retresh view during calculation Folder for output files [Same folder as project file]	< Text files > Delimiter Space Comma Digit Digit Integer 0.1 unit 0.01 unit Output form Matrix Control point form ' VALUE ' ' GRAPH ' ' U' ' ' V' ' UV Bar '
	Drawing How to display calculation time	Victure Tites Victure Clipping area O Application area O Application area
Result of Simulation	Waiting time for drawing result data 0.00 (sec) Drawing period of landslide trigger 10 (sec)	Explain the output file
		Execute Cancel

Setting on the LS-RAPID application

3-5. Setting of conditions for calculation

Click flow [2: Calculation for condition] – [Condition for calculation], or menu [Parameters] - [Conditions for calculation].



Contents	Explanations
Number of CPU threads	Set to the number of CPU cores. The number of CPU cores varies with each PC. If you use all cores for the simulation, it will hinder the performance of other tasks on your PC. Set this number based on your experience.
Calculation time	Set the duration. You need to set this by an area of simulation.
Calculation time (per step)	Set to the time for each calculation step. The number of calculation steps is calculated by the division of calculation time /time for each step. Normally, you set the time interval for the calculation of LS-LAPID.
Output snapshots	Set to output data interval for each step. You have to adjust this number depending on the duration. A value of about 100 is often used.

Contents	Explanations
Manning coefficient	Set to Manning's roughness coefficient. If you want to set this number for each mesh datum, tick [Use parameters on each mesh datum] and click [Manning coefficient mesh editing] to input the number for each mesh datum in a manner similar to inputting an elevation datum.
Folder for output tsunami result files	Designate to a folder for saving the output of the tsunami computing simulation. It is not necessary to change the default folder. All files in this output folder will be deleted after computing processes. Do not designate a folder in which you have stored files that you need.
Boundary conditions	You have to select [Wide area condition] or [Narrow area condition]. The wide area mode uses the conditions for linear progressive waves, and is effective for areas including deep water (for example, the total sea area of Japan). On the other hand, the narrow area mode uses the boundary condition of Sommerfeld type, and is effective for areas including shallow and coastal areas. Then, choose and set 'Reflection' or 'Open' to the squares. Boundary position means Bottom is Y (-) of the coordinate, Top is Y (+), Left is X (-) and Right is X (+) respectively.

The process [2: Calculation condition] – [Condition for calculation] sets Calculation time and Calculation time per step for the tsunami simulation are same as the LS-RAPID calculation.

3-6. Settings for output and visualization

Click flow [3: Simulation] - [Set calculation output], or menu [Execute] - [Set calculation output]. A dialog box below will appears.

Flow	Execute(C) Help(H)
1: Mesh	Set calculation output (S)
2: Calculation condition 3: Simulation	Start simulation (L)
Set calculation output Start simulation Result of simulation	Display the simulation results (R)
	Output satting
	Calculation Step Numbers (for result drawing and saving) How to display calculation time Sec Thur Comments field
	Waiting time for drawing altitude data 0.00 (sec)
	Output options
	Assign the head words for output files 📴 🔯
	Step range to output calculation result

 $\boldsymbol{\cdot}$ Setting for output visualization

Contents	Explanations
How to display calculation time	\bigcirc Sec \bigcirc Hour Set the format for displaying elapsed time.
Comment field	You can display some comments.
Waiting time for drawing altitude data	You can adjust imaging speed with this setting. The initial setting is 0.0. If you want a slower imaging speed, adjust this value.

 $\boldsymbol{\cdot}$ Options for output files

Contents	Explanations
Assign the head words for output files	You can designate the storage of output files and initials of file names.
Step range to output calculation result	If you input values, you will get output data that is between the two values. If you do not set any values, you get the complete output data.
Picture clipping area	○ Application area ○ 3D-View area Settings of the range when you save files as JPEG image or AVI movies. You can set ranges of all or only the 3D view area. If you could not get images properly, set 3D-View area.

3-7. Start the simulation

3: Simulation	Execute(C) Help(H)
	Set calculation output (S)
Set calculation output	Start simulation (L)
	Display the simulation results (R)
Start simulation	
	🕢 🗗 👭 🗰 💵 🕨 🔳 🛛 😤
Result of simulation	Start Simulation

Click flow [3: Simulation] - [Start simulation], or Menu [Execute] - [Start simulation]. Next windows appear and the simulation starts to run.

🦪 Integrated Landslide-Tsunami Simulation Model (LS-Tsunami) - Unzen170301_Tsunami(100m).ltu	
File(E) Edit(E) View(Q) Parameters(P) Execute(C) Help(H)	
· □ ☞ ■ ■ 1 😵 📎 🖉 🖾 🛋 🕢 な 🗗 🗛 🗰 🕨 🖿 📲 😵	
Flow	
1: Mesh	
2: Calculation condition	
D:¥Datas¥LSTsunami¥Unzen(Ra50Tsu100)¥Unzen170301_Tsunami(100m)_Tsunami¥main	Follow.
3580 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	*8 **
set calculation output 3581 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	and the second
3082 / 3600 i-size: 089 j-size: 3/3 layer: 1 / 1	
2500 / 3000 FSIZE: 309 FSIZE: 370 Tayer: 1 / 1	12 ·
Start simulation 3504 / 5000 / S12e, 509 / S12e, 575 / Javer, 1 / 1	
3586 / 3600 i ster 589 i size: 373 laver: 1 / 1	
3587 / 3600 i-size: 589 i-size: 373 laver: 1 / 1	₽ -
Result of simulation 3588 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	
3589 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	
3590 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	
3591 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	
3592 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	
3593 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	
3594 / 3600 i-size: 589 j-size: 3/3 layer: 1 / 1	
▼Axis line ▼ cd 3595 / 3600 i −size: 589 j −size: 373 ayer: 1 / 1	-2453
Lines of mesh 22, 2507 / 3000 I-SIZE: 389 J-SIZE: 373 Iayer: 1 / 1	- And a
2509 / 3000 15126. 309 15126. 373 Tayer: 1 / 1	a second
3500 / 5000 r size, 500 i size, 575 laver, 1 / 1	° 55
Unstable mass 3600 / 3600 i size: 500 j size: 510 jayer: 1 / 1	
Field	
Surface Sliding Runtime = 116.17 sec	s) - 🖓 🖓
*** Computation Terminated ***	
Mass exprettion the simulat	- 12E
Ball Normal Crean	
Stable mass	
Reset view	
レディ Landslide-Tsunami	NUM

If the run finishes properly, the "Computation Terminated" note will appear. Then, Close this calculation window.

3-8. Display the results

3: Simulation	Execute(C) Help(H)
	Set calculation output (S)
Set calculation output	Start simulation (L)
	Display the simulation results (R)
Start simulation	
	∫x (P) 🚧 🚧 💵 🕨 🔳 💡 🦓
Result of simulation	Result Display

Click flow [3: Simulation] - [Result of simulation], or menu [Execute] - [Display the simulation results] to see the visualized results of the simulation.



4. Tsunami simulation

4-1. Simulation Steps

If you want to simulate a tsunami by faulting and other seafloor deformations, select "Tsunami simulation".



The figure below shows the flow diagram of LS-Tsunami simulation



4-2. Setting of simulation area

Click flow [1: Mesh] - [Simulation area], or menu [Edit] - [Setting simulation area and data editing], and input the area of calculation. Setting procedure is similar to LS-RAPID.

Flow 1: Mesh Select analyze method Simulation area Editing of mesh Editing of mesh Edit(E) View(O) Parameters(P) Execute(C) Help(H) Setting simulation area and data editing (P)
2: Calculation condition 3: Simulation Editing of Control Point Transfer control point data to mesh data (C)
Setting of simulation area and input-data type Axial setting of simulation area X-direction Min = 0.000 Max = Y-direction Min = 0.000 Max = Mesh setting of simulation area (Pitch) (Numbers) X-direction 10.000 (m) Y-direction 50 Y-direction 10.000 (m) Y-direction 50
OK Cancel

Flow		E	diting of mea	sh													
1: Mesh			Change head Index	er © P	osition										Po	lygon area	
			Slope Surface	Elevation	Manning	coefficient											
Select analyze method														0.0	Set in sel	lected rect	angle
			Mesh[X] [Y]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
			1	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	71 =
			2	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	71
Simulation area			3	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	71
			4	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	71
	-		5	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	71
	-		6	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	-71
			1	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	-7
Editing of mesh			8	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	-7
			3	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	700.0	7
			11	630.0	630.0	630.0	630.0	630.0	630.0	630.0	630.0	630.0	630.0	630.0	630.0	630.0	6
			12	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	560.0	51
			13	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	490.0	4
			14	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	420.0	4:
			15	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	350.0	3!
			16	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	280.0	21
	-		17	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	210.0	2
			18	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	1. *
2: Calculation condition			<														- F
3: Simulation																	Close

Click Flow [1: Mesh] – [Editing of mesh] to open the window to input topographic data.

If there are some random elevation data other than meshed data, use the function [Transfer control point data to mesh data] to produce meshed data values.

Edit	View(<u>O</u>) Parameters(<u>P</u>) Execute(<u>C</u>) Help(<u>H</u>)							
	Setting simulation area and data editing (P)							
	Editing of Control Point							
	Transfer control point data to mesh data (C)							
Editing of Control Point								

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No.	х	Y	Elev. ZG	^
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Setting to parameters for LS-Tsunami, which is similar with the LS-RAPID.

🝠 Integrated Lar	dslide-Tsunami Simulation Model (LS-Tsunami) - Unze	n1]
File(F) Edit(E)	View(O) Parameters(P) Execute(C) Help(H)	
) 🗅 🗳 🖬 🏢	Setting the view point of topography (V)	
Flow	Reset geographical viewpoint (R)	
1: Mesh	Reset geographical feature	
	Setting of topography view (G)	
Select analyze	Setting of topography color (B)	
	Setting of drawing level-surface range (P)	
	Current figure	×
Simulation	View cross or longitudinal section (C)	
	Output of arbitrary cross section profile (F)	
Editing of I	Display of calculation values	•

Click Flow [2: Calculation condition] - [Condition for calculation] option, or menu [Parameters] - [Conditions for calculation]. If the Manning's coefficient for each mesh is necessary, then click menu [Manning coefficient] to set it.

2: Calculation condition							
	Parameters(<u>P)</u> Execute(<u>C</u>)	Help(<u>H</u>	<u>1)</u>			
Select landslide result	Conditio	ns for calculatio	on (C)				
	Manning	coefficient (M)					
Conditions for calculation	System	environmental setting (S)					
Set condition for calculation							
-Condition of Tsunami simulation -		Fault setting		Add Delete			
Number of CPU threads	2	Setting its	em				
Calculation time	300.0 (sec)	Fault origin X	(m)				
Calculation time (ner sten)	0.100 (sec)	Fault origin Y	(m)				
	10	Rupture time	(sec)				
Output snapsnots	10	Deptn Slin	(m) (m)				
Manning coefficient	0.025	Dip	(degrees)				
Use parameters on each me	sh datum	Strike	(degrees)				
Deursdami anndikiene		Slip angle	(degrees)				
Boundary conditions		Fault length	(m) (m)				
🔘 Deep water depth 🛛 🧿 Sha	llow water depth	Fault Width	(m)	b			
Boundary position Reflection	n Open			,			
Bottom	Open	Folder for output ts	unami result	files 🛛 💆 🔯			
Тор	Open	[Same folder as pro	oject file]				
Left	Open						
Horizontal effect) Yes						
			Set Para	meters Cancel			

Contents	Explanations
Number of CPU threads	Set the number of CPU cores. The number of CPU cores varies with each PC. If you use all cores for the simulation, it will hinder other tasks running on your PC. Set this number based on your experience.
Calculation time	Set the duration. You will need to set this based on the area of the simulation.
Calculation time (per step)	Set to the time for one computing step. You have to adjust this depending on the area and duration of the simulation. A value of about 0.005 is often used here. The number of steps is the total duration / one time interval.
Output snapshots	Set the output data interval for each step. You have to adjust this number depending on the duration. A value of about 100 is often used.

Contents	Explanations
Manning coefficient	Set the Manning's roughness coefficient. If you want to set this number for each mesh datum, check [Use parameters on each mesh datum] and click menu [Parameters] – [Manning coefficient] to input the number for each mesh datum in a similar way of inputting an elevation datum.
Boundary conditions	You have to select [Deep water depth] or [Shallow water depth]. The wide area mode uses the conditions for a linear progressive wave, and is effective for areas including deep water (for example, the total sea area of Japan). On the other hand, the narrow area mode uses the boundary condition of Sommerfeld type, and is effective for areas that include shallow and coastal areas. Then, choose and set 'Reflection' or 'Open' to the squares. Boundary position means Bottom is Y (-) of the coordinate, Top is Y (+), Left is X (-) and Right is X (+) respectively.
Horizontal effect	If you click 'Yes' the program will incorporate the effect of a horizontal component for computing. If a fault occurs on a slope, the initial water surface of its generated tsunami is affected by a horizontal component.
Fault setting	The following parameters are for computation by faulting – crust deformation.
Fault origin X,Y(m)	Coordinates for the original position of the fault surface.
Rupture time (sec)	Time when faulting starts.
Depth (m)	Depth of the top of the fault surface.
Slip (m)	A slip distance on the fault surface.
Dip (degrees)	Maximum dipping angle of the fault surface.
Strike (degrees)	Strike angle of the fault surface. Give this value using North as 0° and increase the angle clockwise.
Slip angle (degrees)	Angle of slip direction on the slip surface. Give this value using the right side of the horizontal surface as 0° and increasing the values anti-clockwise.
Fault length (m)	Length of the fault.
Fault width (m)	Width of the fault.
Folder for output tsunami result files	Designate to a folder saving the output of the tsunami computing simulation. It is not necessary to change the default folder. All files in this output folder will be deleted after computing. <u>Do not</u> designate a folder in which you have stored files that you need.

If the Manning's roughness coefficient for each mesh datum is necessary to set, then click menu [Parameters] - [Manning coefficient] option.

The window below shows the table to set a Manning's roughness coefficient for each mesh datum.

hange head Index	er	osition											Polygon	area 🧧	P
ope Surface	Elevation	Manning	coefficien	t											
0.1	025 S	et in sele	cted recta	ingle											
Mesh[X] [Y]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	ľ
1	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	-
2	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
3	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
4	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
5	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
6	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
7	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
8	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
9	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
10	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
11	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
12	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
13	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
14	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
15	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
16	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
17	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
18	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
19	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	
20	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	•
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Schematic sketches of a fault model and faulting parameters.



Figure 1. Fault model and faulting parameters (bold arrow indicates the direction of movement of the hanging wall on the footwall)



Figure 2. Different form types of faults

(from Handbook of Fault Parameters pp.24-25 (In Japanese) Kajima Publishing, 1989)

4-5. Settings for output and visualization

Flow	Evenute(C) Help(H)
1: Mesh	
2: Calculation condition	Set calculation output (S)
3: Simulation	
	Start simulation (L)
Set calculation output	Display the simulation results (R)
Start simulation	-
E	
Result of simulation	
-	

Click flow [3: Simulation] - [Set calculation output] option, or menu [Execute] - [Set calculation output]. A dialog box below will appears.

Calculation Step Numbers (for result drawn How to display calculation time Sec Comments field	ing and saving) Houri
Waiting time for drawing altitude data	0.00 (sec)
Output options Assign the head words for output files	i
Step range to output calculation result < Picture Files >	
☐'JPEG'Files ☐'AVI'File Picture Clipping Area	10 (frames/sec)
Application Area	Explain the Output File

 $\boldsymbol{\cdot}$ Setting for output visualization

Contents	Explanations
How to display calculation time	\bigcirc Sec \bigcirc Hour Set the format for displaying elapsed time.
Comment field	You can display some comments.
Waiting time for drawing altitude data	You can adjust imaging speed with this setting. The initial setting is 0.0. If you want a slower imaging speed, adjust this value.

 $\boldsymbol{\cdot}$ Options for output files

Contents	Explanations
Assign the head words for output files	You can designate the storage of output files and initials of file names.
Step range to output calculation result	If you input values, you will get output data that is between the two values. If you do not set any values, you get the complete output data.
Picture clipping area	○ Application area ○ 3D-View area Settings of the range when you save files as JPEG image or AVI movies. You can set ranges of all or only the 3D view area. If you could not get images properly, set 3D-View area.

4-6. Start the simulation

3: Simulation	Execute(C) Help(H)
	Set calculation output (S)
Set calculation output	Start simulation (L)
	Display the simulation results (R)
Start simulation	
	🕢 🗗 👫 👫 💷 🕨 🖉 🤔
Result of simulation	Start Simulation

Click flow [3: Simulation] - [Start simulation] option, or menu [Execute] - [Start simulation]. Next following windows appear and the simulation starts to run.

Integrated Landslide-Tsunami Simulation Model (LS-Tsunami) - Unzen170301_Tsunami(100m).ltu \[
File(<u>F</u>) Edit(<u>E</u>) View(2) Parameters(P) Execute(C) Help(H)			
<u> </u> L 🖻 🖪 🎟 🔊 🖇	≥ ⊘ ≜ = → fx B ' AA AA ▶ ■ ? 8 %			
Flow				
1: Mesh				
2: Calculation condition		/		
3: Simulation	💷 D:¥Datas¥LSTsunami¥Unzen(Ra50Tsu100)¥Unzen170301_Tsunami(100m)_Tsunami¥main 👝 🗉 📧	12634		
	3580 / 3600 i-size: 589 j-size: 373 layer: 1 / 1 🛛 🗛	· 35 %		
Set calculation output	3581 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	and the second s		
	3582 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	1 A A A A A A A A A A A A A A A A A A A		
	3583 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	S J R .		
Start simulation	3584 / 3600 i-size: 589 j-size: 373 layer: 1 / 1			
	3585 / 3600 i-size: 589 j-size: 373 layer: 1 / 1			
	3086 / 3600 i-size: 089 j-size: 373 layer: 1 / 1 2507 / 2000 i-size: 500 i-size: 272 layer: 1 / 1	S.S.S.		
Result of simulation	3007 / 3000 FSIZE; 300 JSIZE; 373 Tayer; 1 / 1 2509 / 2600 i-cito; 509 i-cito; 272 Tayer; 1 / 1			
	2500 / 3000 FSIZE, 300 J-SIZE, 373 Tayer, 1 / 1 2589 / 3600 i-size, 589 i-size, 373 Tayer, 1 / 1	1917 A.		
	3500 / 3600 isize: 589 isize: 373 layer: 1 / 1			
	3591 / 3600 i-size: 589 i-size: 373 laver: 1 / 1			
	3592 / 3600 i-size: 589 i-size: 373 laver: 1 / 1	•		
	3593 / 3600 i-size: 589 j-size: 373 layer: 1 / 1			
Display setting	3594 / 3600 i-size: 589 j-size: 373 layer: 1 / 1			
🗸 Axis line 🛛 🗸 Co	3595 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	Sec. Start		
	3596 / 3600 i-size: 589 j-size: 373 layer: 1 / 1	A CON		
Lines of mesn 20	3597 / 3600 i-size: 589 j-size: 373 layer: 1 / 1			
✓ Base elevation	3598 / 3600 i-size: 589 j-size: 373 laver: 1 / 1	1998 - 1998 - 1998 - 1998 - 1998 - 1998 - 1998 - 1998 - 1998 - 1998 - 1998 - 1998 - 1998 - 1998 - 1998 - 1998 -		
Unstable mass	3599 / 3600 i-size: 589 j-size: 373 laver: 1 / 1	202		
Field	3600 / 3600 i-size: 589 j-size: 373 Tayer: T / T	SASS A		
Surface Sliding	Rustino - 116 17 coc	- Jak		
	Xantine - Tro. 17 Sec			
Mass exprettion the simulat				
🔘 Ball 🔘 Normal 🔘	16.01	4		
Stable mass				
Reset view	Γ Φ			
レディ	Landslide-Tsunami	NUM		

If the run finishes properly, "Computation terminated" note will appear. Then, Close this window.

4-7. Display the results

3: Simulation	Execute(C) Help(H)
	Set calculation output (S)
Set calculation output	Start simulation (L)
	Display the simulation results (R)
Start simulation	
Result of simulation	Result Display

Click flow [3: Simulation] - [Result of simulation] option, or menu [Execute] - [Display the simulation results] to see the visualized results of the simulation.



5. Base Study

The scientific use of LS-RAPID Landslide Simulation and LS-Tsunami Simulation could be observed from the paper below:

Sassa K, Dang K, Yanagisawa H, He B (2016) A new landslide-induced tsunami simulation model and its application to the 1792 Unzen-Mayuyama landslide-and-tsunami disaster, Landslides 13:1405-1419. DOI 10.1007/s10346-016-0691-9