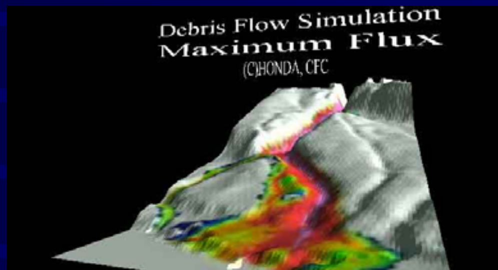
Debris Flow Simulation



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Background

- Debris flow is a phenomena that high density water with mud and big gravel flows down along a stream at high speed.
- Because of its high density and speed, it has huge destruction power. Sometimes it flows over even high ridge of mountains.
- Thus damages by debris flows are very severe and sometimes tragic. It destroys houses, bridges and infrastructure and claim people's lives.

Debris Flow Hit Houses
29 Jun 1999 in Hiroshima, Japan

- 1999年6月29日　広島の豪雨災害
- 安佐北区亀山9丁目の土石流
- 谷の源頭部の崩壊によって発生した土石流は，狭い谷を高速でかけ下り，谷の出口で斜め方向に飛び出し民家を直撃した．この付近には比較的硬質の細粒花崗岩が分布する．マサ化の程度は低く，斜面には崖錐(過去の土石流堆積物)が多く分布する．
- Courtesy: Asia Air Survey Company HP
- http://www.ajiko.co.jp/topics/ct/hiroshima/hiroshima2.html

Debris Flow Hit Housing Compound
29 Jun 1999 in Hiroshima, Japan

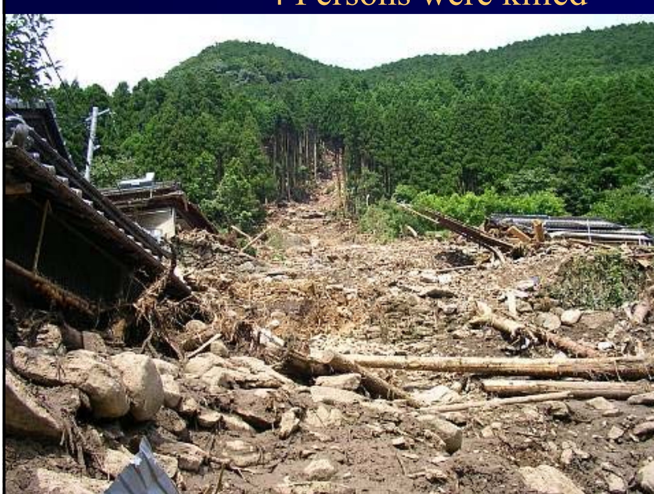
1999年6月29日　広島の豪雨災害

佐伯区屋代（やしろ）

上流で発生した土石流が，西広島バイパスの下のボックスカルバートを通過，下流の屋代地区で氾濫，住宅地に大きな被害をもたらした．

- Courtesy: Asia Air Survey Company HP
- http://www.ajiko.co.jp/topics/ct/hiroshima/hiroshima2.html

Debris Flow Hit Housing Compound
20 July 2003 in Minamata, Kyushu, Japan
4 Persons were killed



水俣市深川･新屋敷地区の土石流

7月20日03:30頃発生し，一家4人が死亡とのこと(7/21西日本新聞)．流下幅は集落付近で10m．勾配が非常にきつく，集落付近で20度程度，上流側の林内で31度程度．

Courtesy: Mr. Ushiyama's HP

www. disaster-i.net

http://kodama.civil.tohoku.ac.jp/photo/030722/index901.html

Background-2

- Numerical simulation is important for planning efficient counter measures.
- In Japan, intensive simulation technique researches have carried out since 1980s.
- Model development is based on
  - Expansion of shallow water simulation
  - Intensive experiment to model the movement
  - Internal structure; resistance law
  - Leap Frog Simulation
- Especially 2D simulation is powerful to evaluate various scenarios and damages in deposition area.

Background-3

- 1D and 2D simulation software were developed on FORTRAN with a support and collaboration from JFEC (Japan Forest Engineering Consultants Foundation) and Tsukuba University.
- 1D simulation for starting point to the top of the alluvial fan.
- 2D simulation to simulate the movement of debris flow on the alluvial fan.

Equations for 1D

- Equations for 1D

Continuity Equation

$$\frac{\partial h}{\partial t}+\frac{\partial M}{\partial x}=E$$

$$\frac{\partial ch}{\partial t}+\frac{\partial cM}{\partial x}=Ec_*$$

Motion Equation

$$\frac{\partial M}{\partial t}+\frac{\partial uM}{\partial x}=-gh\frac{\partial H}{dx}-\frac{\tau_b}{\rho_m}$$

h : flow depth
u : cross section averaged speed
M : Flux $(=hu)$
c : Sediment Density of the flow
E : Erosion Speed
c_* : Sediment Density at riverbed deposit
ρ_m : averaged unit weight of the flow
τ_b : Shear Resistance at the riverbed level
H : elevation of the flow

Shear Resistance

- Shear Resistance

Continuity Equation

$$\tau_b=\tau_y+\tau_D=\tau_y+\rho f_b\overline{u}^2$$

τ_b : Shear Resistance at the riverbed level
τ_y : Coulomb friction force
τ_D : Dynamic friction force
f_b : Resistance Coefficient

Erosion Speed

Erosion Speed Equation : Egashira

$$\frac{E}{|u|} = \tan(\theta - \theta_e)$$

θ_e : Equilibrium slope for $\bar{c}$

$$\tan\theta_e = \frac{\bar{c}(\frac{\sigma}{\rho} - 1)}{\bar{c}(\frac{\sigma}{\rho} - 1) + 1}\tan\phi_s$$

Expansion to 2D

Continuity Equation

$$\frac{\partial h}{\partial t} + \frac{\partial M}{dx} + \frac{\partial N}{dy} = E$$

$$\frac{\partial ch}{\partial t} + \frac{\partial cM}{\partial x} + \frac{\partial cN}{\partial y} = Ec_*$$

Motion Equation

$$\frac{\partial M}{\partial t} + \beta\frac{\partial(uM)}{\partial x} + \beta\frac{\partial(vM)}{\partial y} = -gh\frac{\partial H}{\partial x} - \frac{\tau_{bx}}{\rho_m}$$

$$\frac{\partial N}{\partial t} + \beta\frac{\partial(uN)}{\partial x} + \beta\frac{\partial(vN)}{\partial y} = -gh\frac{\partial H}{\partial y} - \frac{\tau_{by}}{\rho_m}$$

Work Flow of Simulation

- Rainfall under certain return period
- Estimation of inflow
- Development of longitudinal cross section of the stream and DEM
- Decision of parameters
- Estimation of sediment distribution
- 1 DIM simulation down to the top of the alluvial fan
  - Assumption; sediment in the stream is saturated
- 2 DIM simulation from the top of alluvial fan
  - Inflow both in total volume and sediment concentration
- Visualization

Study Area

- Applied in Sakurajima and Youtei-san
  - Sakurajima (Saido and Hase river)
  - Youtei-san (Aoki no sawa, Taki no sawa)
  - 1/5,000 DEM (5m Grid)
- 1Dim (4 hours)
  - Rainfall 90mm/hour (return period: 100 years)
- 2Dim (6 hours)
  - Source Code Example
  - Inflow (Saido River)
    - # Total_Q 462,078 m3
    - # Total_S 107,283 m3
    - # Average_C 0.23

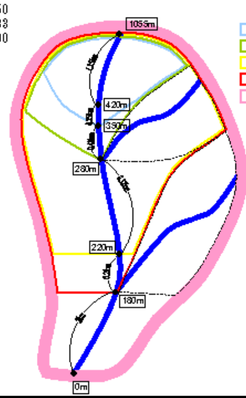
1dim simulation input data

１００年確率時間雨量　　90 mm/h　　長谷川

任意地点における集水面積と最大洪水流量（合理式）

位置	集水面積 ha	雨量強度 mm/h	流下時間	降雨特性係数	土砂混入	流出係数	最大洪水流量 m3/S	c		水平逓加距離	逆水平逓加距離
350mまで	62	118.44	30.7	1.316	1	0.9	18.36		82	3338	1329.1
280mまで	72	114.30	33.56	1.270	1	0.9	20.57		54	2792.4	1874.7
220mまで	85	109.80	37.03	1.220	1	0.9	23.33		35	2357.9	2309.2
180mまで	100	108.27	38.36	1.203	1	0.9	27.07		15	1973.5	2693.6
0mまで	143	98.19	48.64	1.091	1	0.9	35.10	A		0	4667.1
発生地点での最大洪水流量							16.9459		95	3687.1	980.0
標高 100mでの最大洪水流量											2624.1

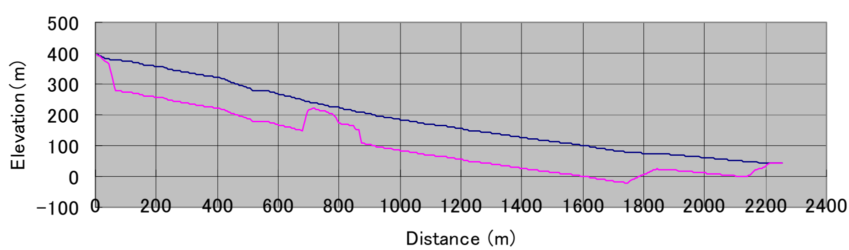
22.8600	46.70298
25.9250	
30.0750	
39.0033	
0.0000	



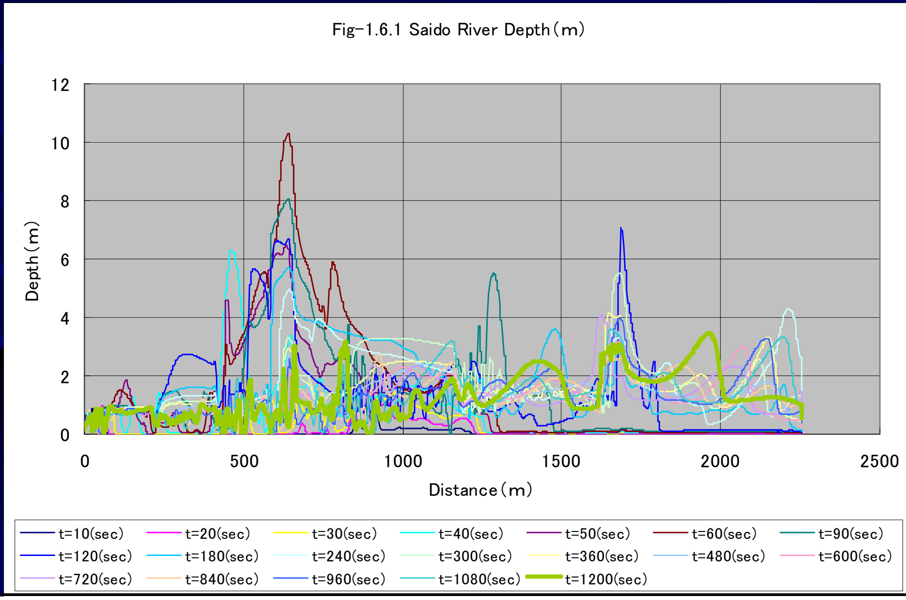
P100	600	600
PC	384	368.312
m	0.67	0.67
Tc	7	7
1	38.8	37.17
2	44.4	42.60
3	56.7	54.39
4	104.3	100.00
5	56.7	54.39
6	44.4	42.60
7	38.8	37.17
	384.0	368.3

1dim simulation input data
Saido River Profile

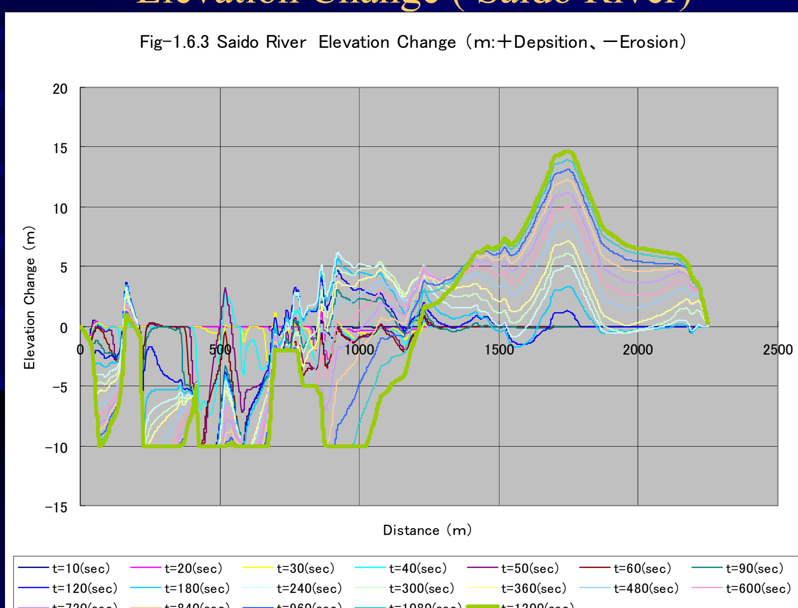
Fig-1.5.1 Saido river Longitudinal Cross Section and Bed Rock (minimu elevation) (m)



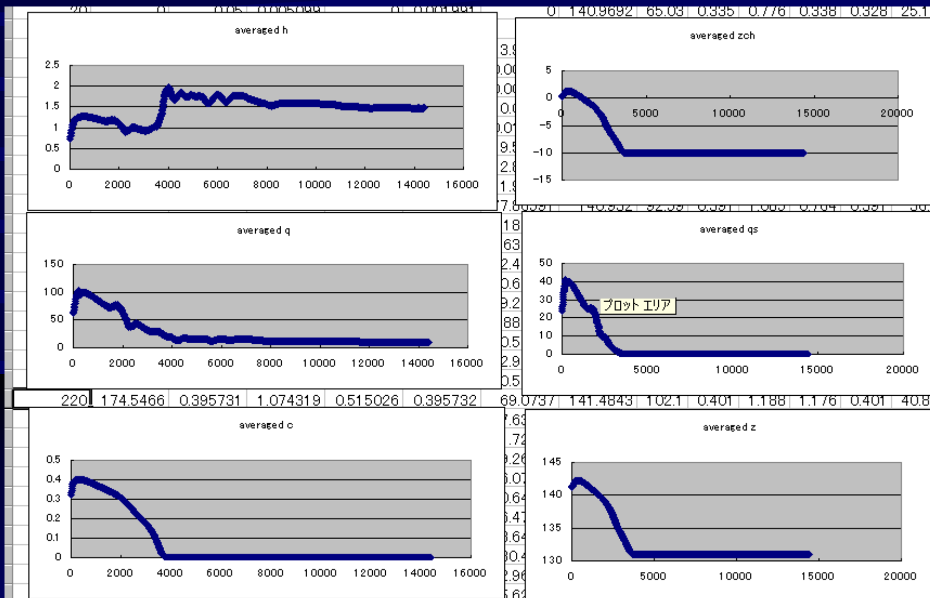
1dim simulation output data
Saido River Depth



1dim simulation output data
Elevation Change (Saido River)



1dim simulation output data



2-Dim Simulation Output Data and their Visualization Step

- Grid data at each time step
  - Height, Slope (X,Y, Total)
  - Flux(X, Y & total)
  - Velocity(X,Y,Total), Sediment concentration (grid and transported)
  - Elevation and its change
  - And etc.

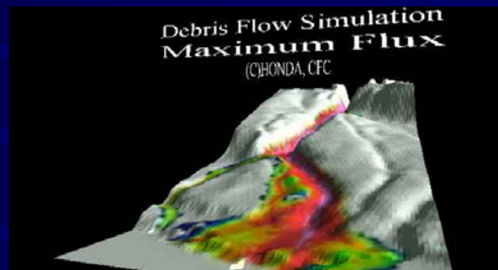
- Visualization
  - Tiff files
  - QT Movies
  - VRML for 3D

2-Dim Simulation Result

Saido River

Flux, Height

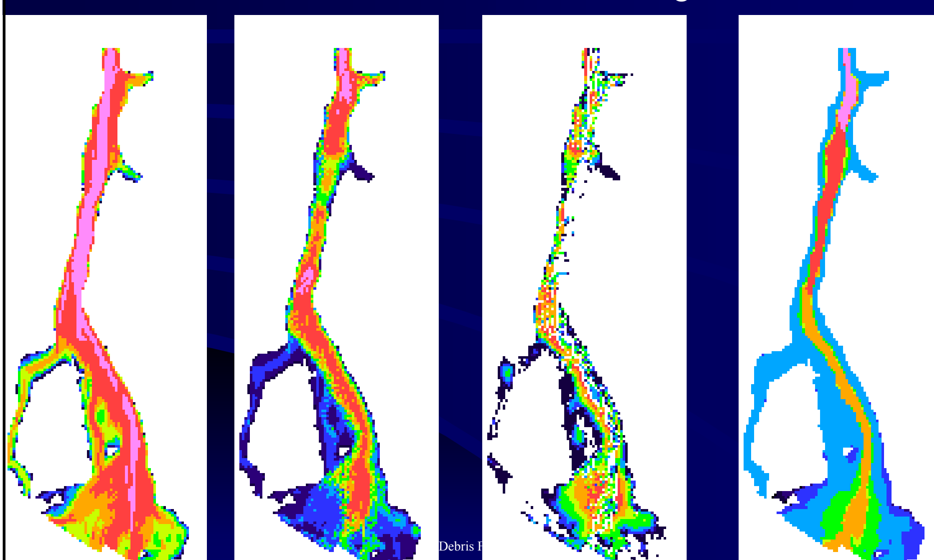
Flux in VRML



These animation can be seen at
http://www.star.ait.ac.th/~honda/debris.html
(Animation Viewer (QT and VRML Viewer) can be downloaded free of charge)

2-Dim Simulation Output

Max. Flux | Max. Depth | Elevation Change | Arrival Time



Advantage & Limitation

- Physical model to reconstruct the phenomena
- Scenario simulation
- Visualization
- Education

- Rainfall Scenario
- Sediment volume scenario
- Accuracy
- Calculation Time

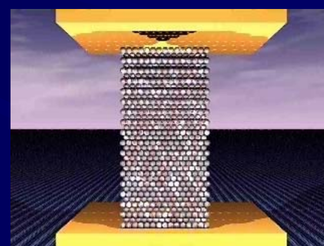
Further Study

- Application in Thailand
- Petchabun disaster in Thailand
- DEM
  - SRTM-3 Data was released
- Rainfall Data

Further Study

- Simulation for more complicated scenario and situation
  - Debris flow with trees, being washed away, flowing with debris flow, dam up at bridges and makes the flow over flow.
  - Hit houses and destory
- Interpolated Differential Operator (IDO)
- Discrete Element Method
- Collaboration with TITECH

Landslide Movie
Switch to DivX



Thank you

http://www.ait.ac.th/~honda

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