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島根大学（松江）

気象・洪水災害研究グループの紹介
マルチ指標による洪水ハザードマップの開発

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気象・洪水災害研究グループの紹介

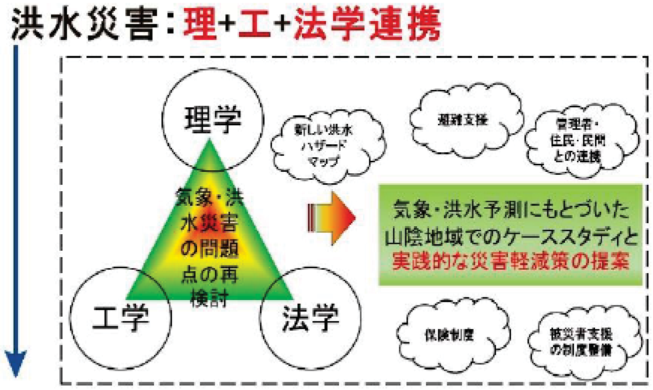
ミッション：

「近年の山陰地域の気象・洪水災害の特徴を整理し、具体的な避難支援や超過洪水対策などについても現地調査、数値シミュレーション、室内実験などから検討するとともに、河川管理法、被害者救済に関する諸制度とその実態を含めたソフト面の不足点を把握する。」

田坂郁夫（気象災害学）：近年における気象災害被害データの整理
→気象災害データベースの更新

増本清（水文地質学）：地下水流動解析と洪水災害の関連性解明
→逆解析による地下地盤の透水性評価

石井将幸（地域基盤工学）：浸水想定区域に指定されていない中山間地域に対する洪水災害の危険度評価と住民への提示手法の開発
→地形等に基づいて算出が可能な、洪水の危険度を評価する指標の検討・提案



佐藤裕和（河川工学）：超過洪水を前提にしたハード・ソフトの検討
→水害防備林の土砂捕捉効果などに関する検討

磯村篤範（公法学）：河川災害に対する法的支援策の構築
→公助・共助・自助と災害社会的再配分、救済制度の検討

永松正則（公法学）：防災の観点から開発許可規制が行われる事例と争訟事例の整理・検討
→開発許可により災害発生の危険がある周辺地域住民の権利救済に関する裁判例の検討

Thu., March 16 2017
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No.215

マルチ指標による洪水ハザードマップの開発
NEW FLOOD HAZARD MAP WITH MULTIPLE INDICATORS

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Introduction

Background

- Municipalities in Japan have been obliged to make a flood hazard map(FHM) since 1994
  → achievement is 98% around as of Mar., 2015(MLIT, 2017)
- Most of these expressions on a FHM are used only inundation water depth
- However, actual evacuees in the case of inundation need more information
  → velocity, force, reaching time, etc. by inundation
  (Katada et al.(1999), Katada et al.(2000), Islam & Sado(2000), Tingsanchali & Karim(2005), EXCIMAP(2007), Onishi et al.(2008), Matsuo et al.(2012), Kawanaka & Ishigaki(2012), Nojima et al.(2014), You & Kondo(2015))
  → new technics using animations or movies on a display are being developed
  (Yokotsuka(2006), Kodama et al.(2013), Kawasaki & Suzuki(2013))

Purpose

- To provide a new FHM integrated with multiple indicators(MFHM = Multi-indicator Flood Hazard Map) in a leaflet or a booklet
  → using animations are effective, but is currently not universal for every user

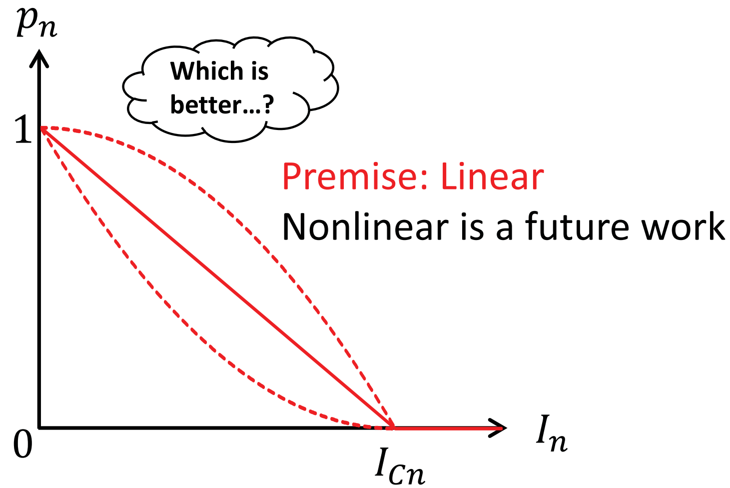
Methodology; expansion to MFHM

① Normalization of parameters

- Different units cannot be combined
  → $h[\mathrm{m}] + v[\mathrm{m/s}] + F[\mathrm{N}] + \cdots \rightarrow ??$
  → $h[\mathrm{m}] \times v[\mathrm{m/s}] \times F[\mathrm{N}] \times \cdots = ??$
- Each index is normalized by its criterion for evacuation limit due to age, sex, mental and physical conditions and so on
- Considering later procedure, this normalized value is subtracted from 1

$$\boldsymbol{p_n = 1 - {}^{I_n}/_{I_{Cn}}\ ,\ p_n > 0}$$
$$\boldsymbol{= 0\ ,\ p_n \leq 0}\ \rightarrow \text{impossible to evacuate}$$

n: number of parameters(n=1, 2 ,...,N)
p_n: normalized point ($0 \leq p_n \leq 1$)
I_n: value of nth indicator
ex.) water depth, velocity, force, time, etc.
I_{Cn}: criterion value of nth indicator



Methodology; expansion to MFHM

② Integration of normalized points

- $p_1 + \cdots + p_N$ increses the total points as the number of indicators increases
- Its arithmetical mean causes a contradiction that evacuation may be possible even when $p_n = 0$
- $p_1 \times \cdots \times p_N$ approaches 0 as the number of indicators increases
- The geometrical mean was adopted to calculate integrated value $P'(0 \leq P' \leq 1)$.

$$\boldsymbol{P' = (p_1 \times \cdots \times p_N)^{1/N}}$$

→ If there is even one 0 of p_n, $P' = 0$

③ Scoring

- P' is safety/dangerous for 1/0, but it's reverse to existing FMS
- To resolve this reverse, P' is subtracted from 1
- To promote intuitive understanding of residents, the final degree of danger P was expressed with scores of up to 100

$$\boldsymbol{P = 100(1 - P')}$$

→ $0 \leq P \leq 100$
safety⇔dangerous

➡ ***P* is used on a MFHM!**

Methodology; expansion to MFHM

④ Indexes used in this study

- Inundation water depth for breathing in a still state
- Rise time of inundation water depth for evacuation possibility from facing to inundation
  → defined as time to evacuation limit of water depth from just after inundation has arrived
- Velocity of inundation for swimming evacuation
- Fluid force by inundation water for evacuation on foot

Criteria of normalization

- Target here is healthy adult males with 170cm average height(MHLW, 2016)

Index	Criterion	Reference
Depth	1.445m	1.7m × 0.85→mouth position
Rise Time	1.5km/45min	Biwako Office, MLIT(2007)
Velocity	1m/s	The slowest criterion of crawl by JASF(2016)
Fluid Force	$1.2m^3/s^2$	Ishigaki et al.(2006)

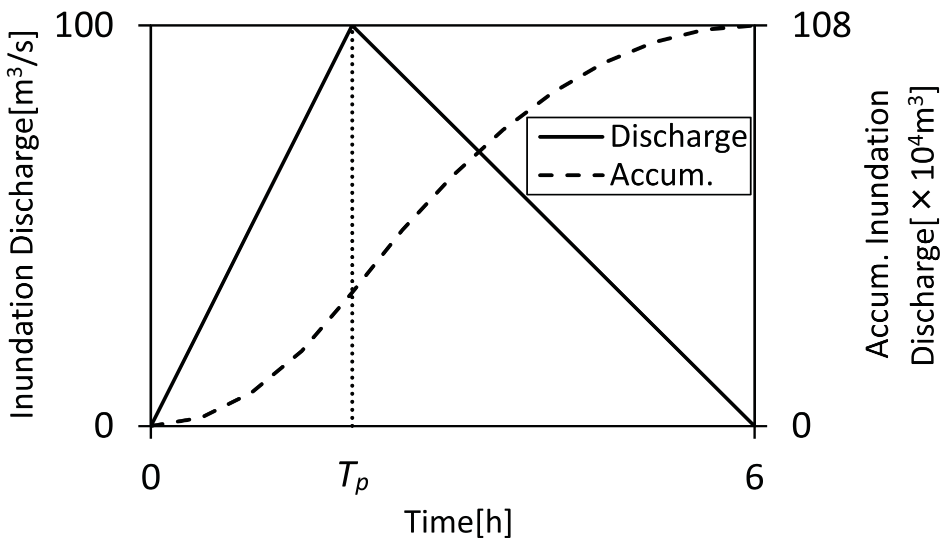
Preliminary numerical experiment

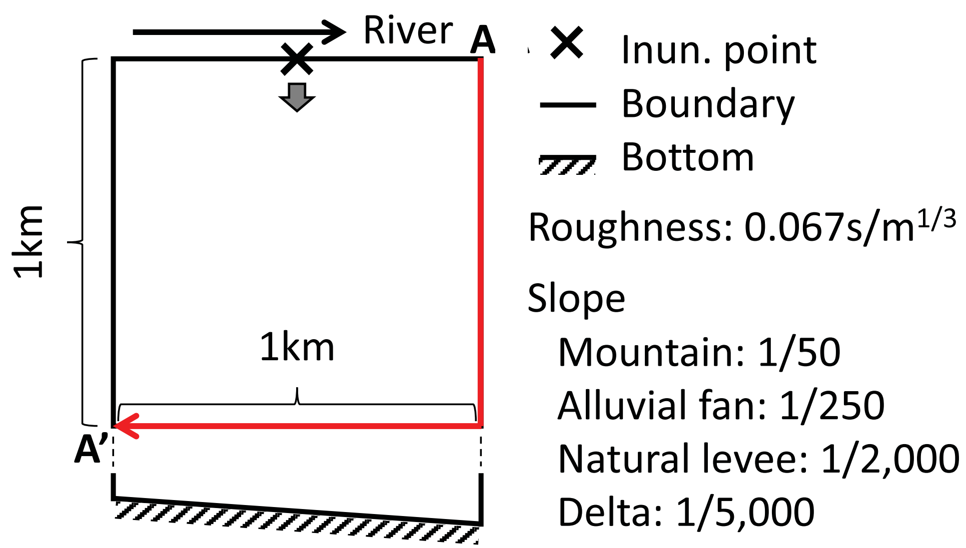
Calculation

- The purpose is to understand fundamental properties of the MFHM
- 2D dynamic wave model, leap-frog method, $\Delta x = \Delta y = 25\mathrm{m}$, calculation time is $48\mathrm{h}$
- 4 model terrains(mountain, alluvial fun, natural levee and delta)
- Inundation hydrograph is a one-peak triangular

  $\rightarrow Q_p = 100\,\mathrm{m^3/s}\,, V = 1.08 \times 10^6 \mathrm{m^3}, \bar{h} \approx 1\mathrm{m}$

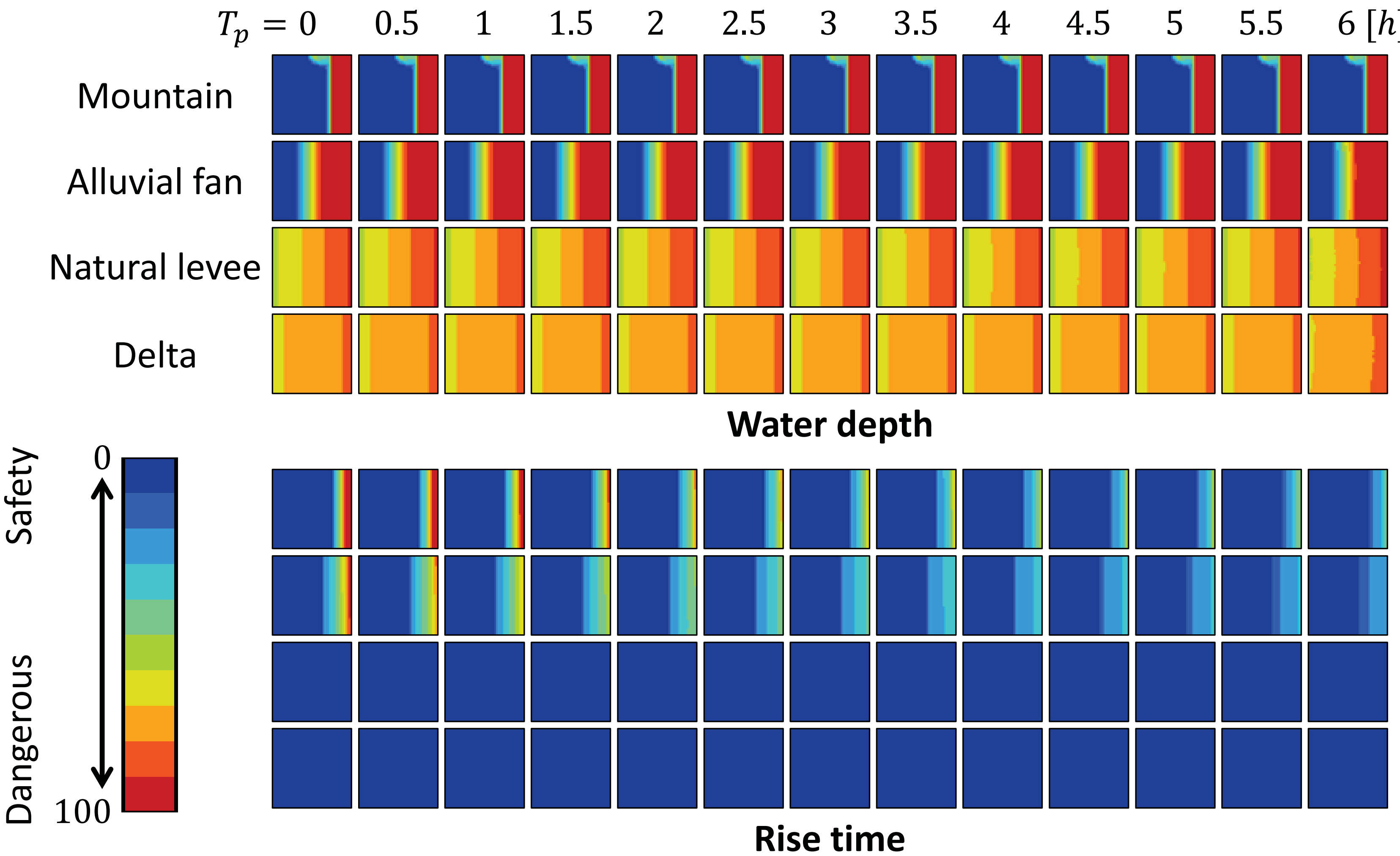
  $\rightarrow T = 6\mathrm{h}, T_p = 0, 0.5, 1, \ldots, 5.5, 6[\mathrm{h}]$(13 patterns of T_p)
- The longest path to evacuate is $2\mathrm{km}$(A to A'), so rise time criterion is $60\mathrm{min}$





Preliminary numerical experiment

Maximum scores of water depth and rise time

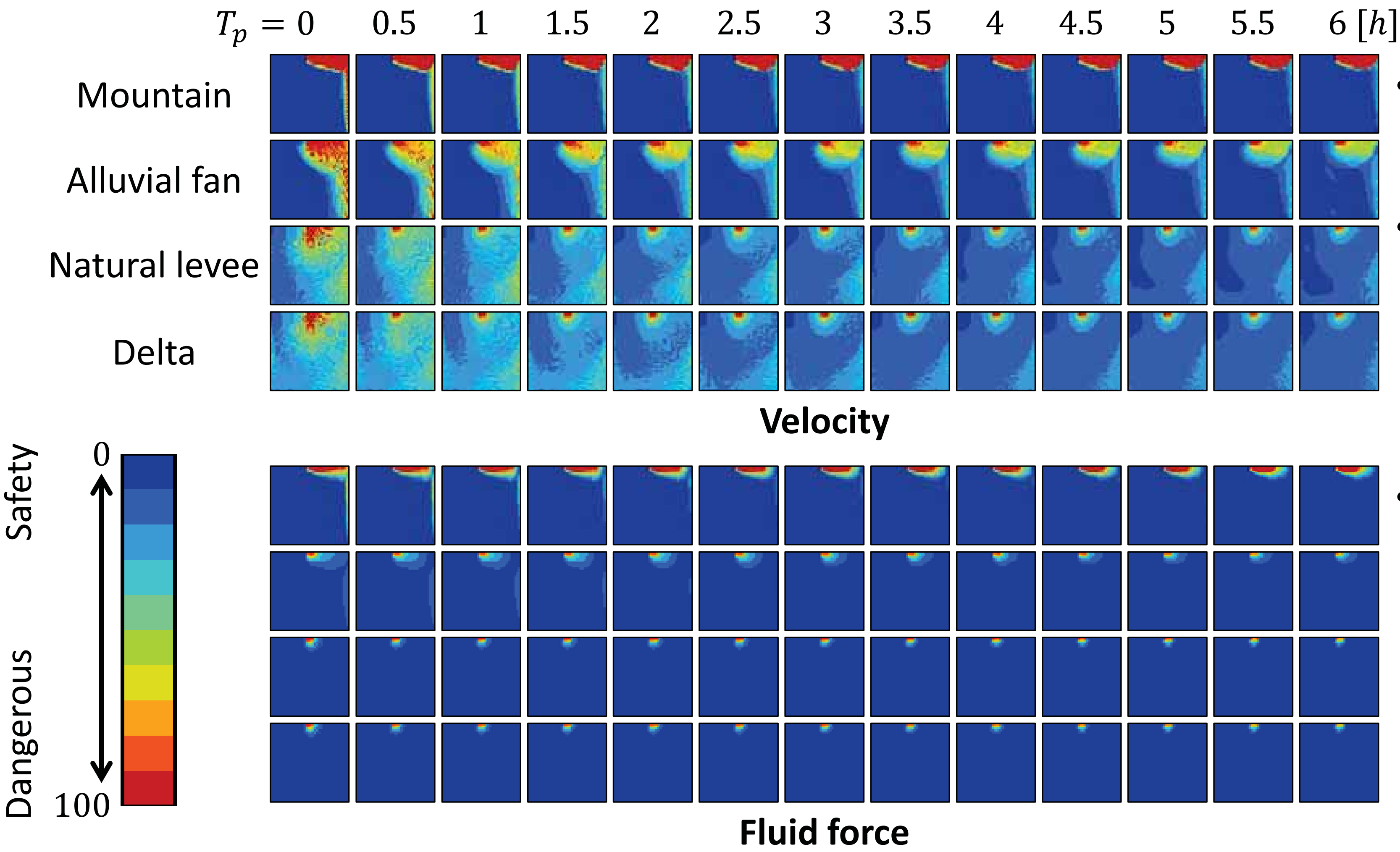


- Same distributions in each terrain regardless to shape of hydrographs
  → V is common
- The milder, the more diffusive

- Some dangerous scores have occurred in 2 steep terrains as T_p earlier
- No dangers in 2mild terrains

Preliminary numerical experiment

Maximum scores of velocity and fluid force

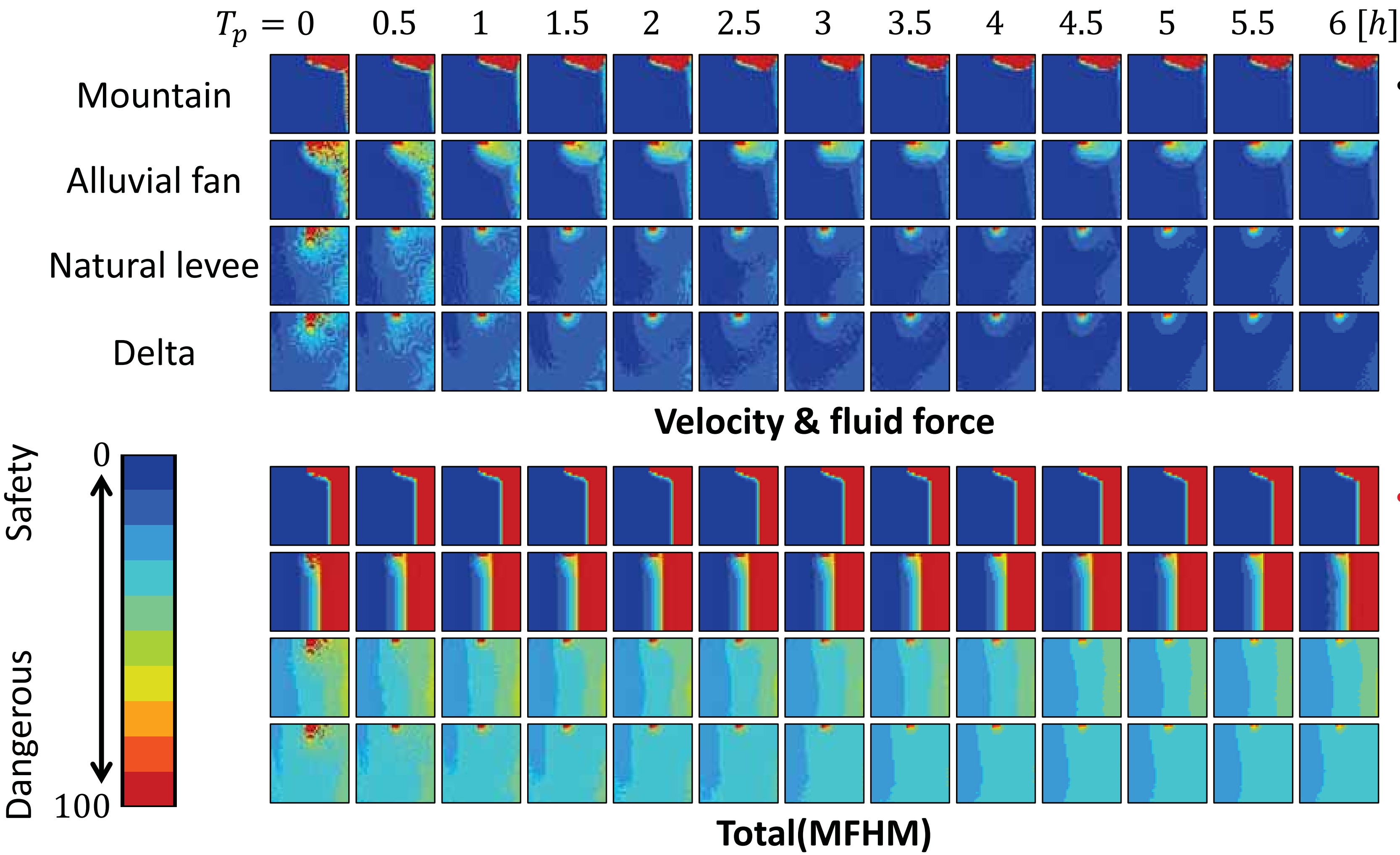


- The steepest one shows dangerous along the river regardless to hydro.
- Dangers in other 3 ones have almost concent-rated only around the inundation point

- Dangers have appeared around the inundation point in all cases

Preliminary numerical experiment

Maximum scores of velocity & fluid force and total

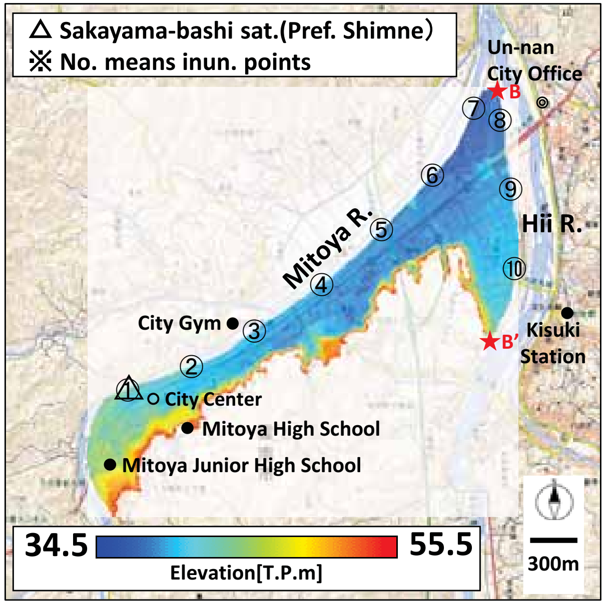


- Similar to velocity
- Dangers were extracted around the inundation point comparison with only depth
  → may need to consider about external forces except water depth

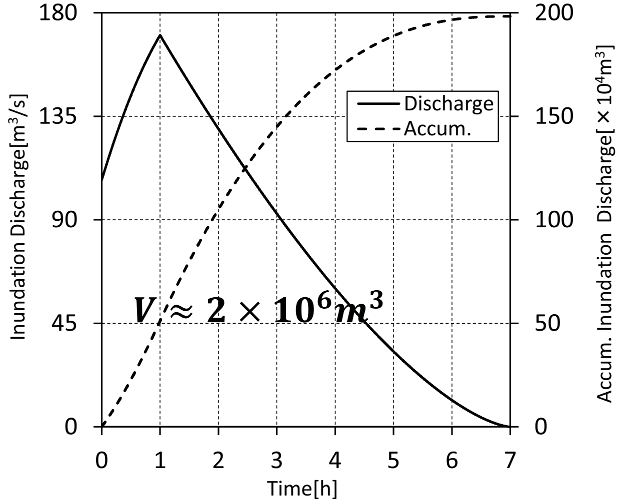
Actual case in central Mitoya, Shimane

Conditions

- Central Mitoya is located in eastern part of Shimane, where is a typical medium city in San-in region
- Elevation(5mDEM) and land use(2009) were obtained from GSI, Japan
  → $5m$-mesh was made by I.D.W. after conversion into UTM-plane
  → standard vales were applied to Manning's roughness
- Criterion for rise time here is also 60min
  → the longest path for evacuation is also 2km from lower part to higher along the Hii river(B to B')
- Hydrograph was made using past water levels, elevation deference between land and river, design-flood discharge, levee-constriction stage slope, etc. at Sakayama-bashi sta.
  → duration is 7h, height of levee break is 1.8m
- Inundation points are 10 including the Hii R. every 500m pitch with the same hydrograph



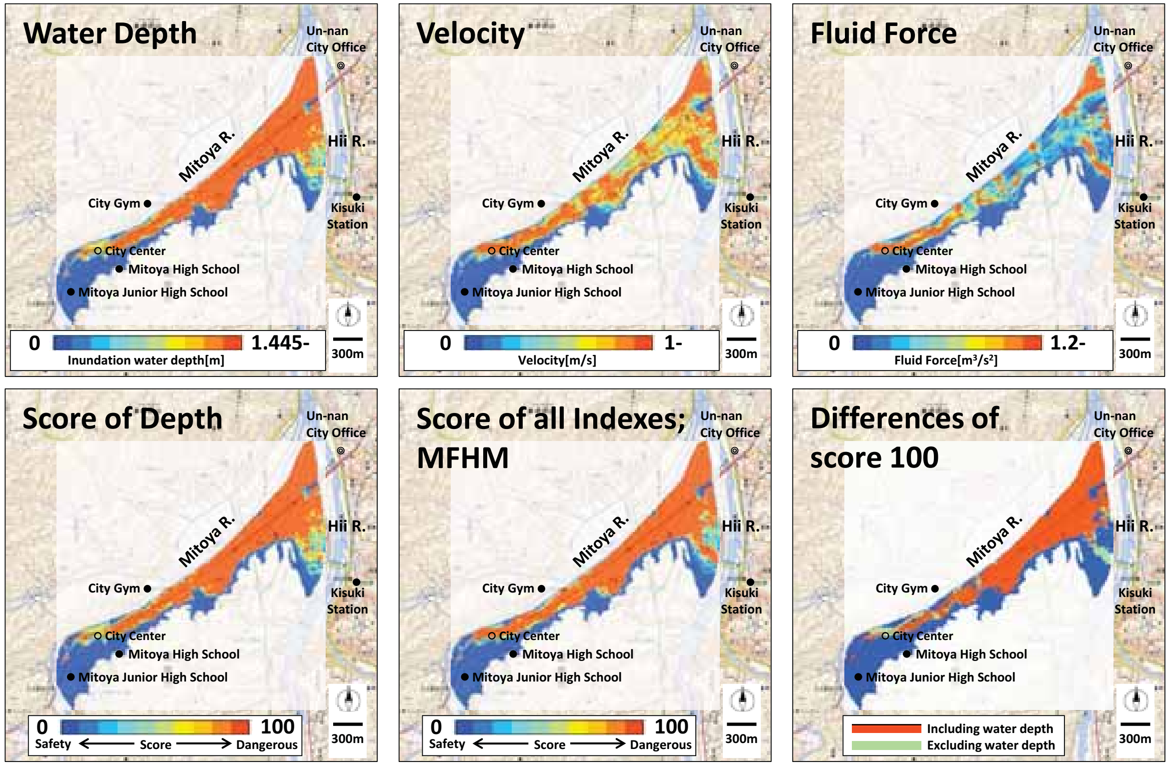
(added to 1/25,000 national topographic map, GSI)



Actual case in central Mitoya, Shimane

Results

- Enveloped maximum values of 10 cases

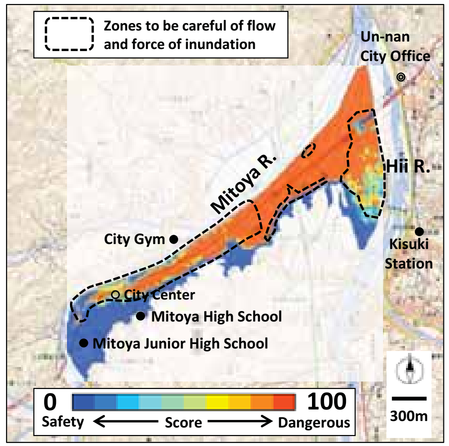


(added to 1/25,000 national topographic map, GSI)

- 12% of areas with score 100 excluding water depth were revealed with MFHM!

Devise of expression for MFHM

- There may be fear of misunder-standings for MFHM users because of a lot of information
  - → Katada et al.(2007), Tanaka & Kato(2011), and the guideline(MLIT, 2013) also has pointed it out
- Especially, Katada et al.(2007) suggested "Rough Map" for FHM
- Applied it to MHFM below



(added to 1/25,000 national topographic map, GSI)

Conclusion

Achievements

- Integrated some indicators against conventional FHM using only inundation water depth
- Suggested MFHM expressed with scores up to 100
- Numerical simulations were executed with 4 model terrains and 13-peak hydrograph and in Mitoya as an actual case
- Using only inundation water depth could not provide enough information for evacuees
- MFHM has potential to give users more effective information with appropriate indicators and expressions

Future

- Nonlinear normalized points
- More effective way to express of MFHM
- How do actual users feel MFHM?
- Is MFHM truly better than FHM?

Acknowledgment

We sincerely appreciate Mr. SEO Tatsuki and Mr. SASAKI Takayuki who are civil engineers of Shimane prefecture for helping information arrangements.

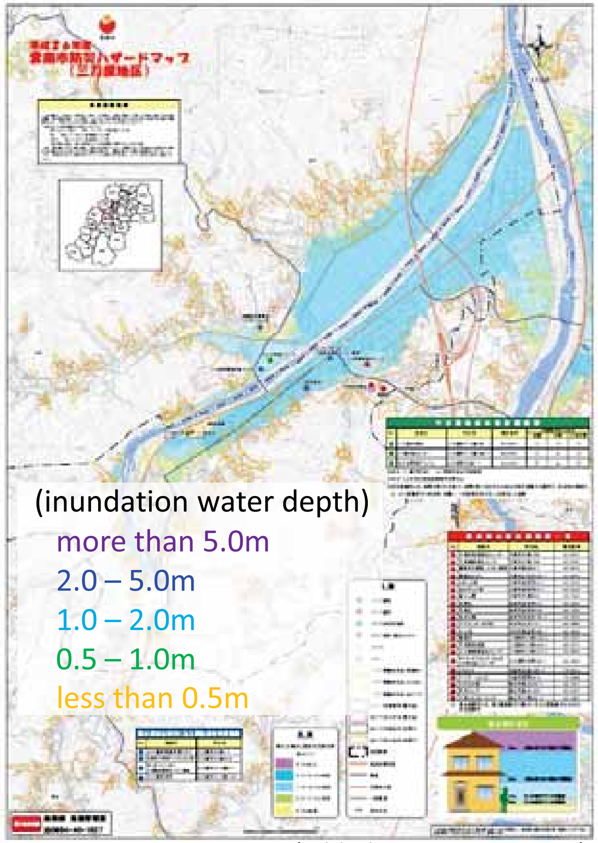
And we must thank Project Center on Natural Disaster Reduction※ established in Shimane University for financial support.

※島根大学自然災害軽減プロジェクトセンター

Thanks for your attention!!

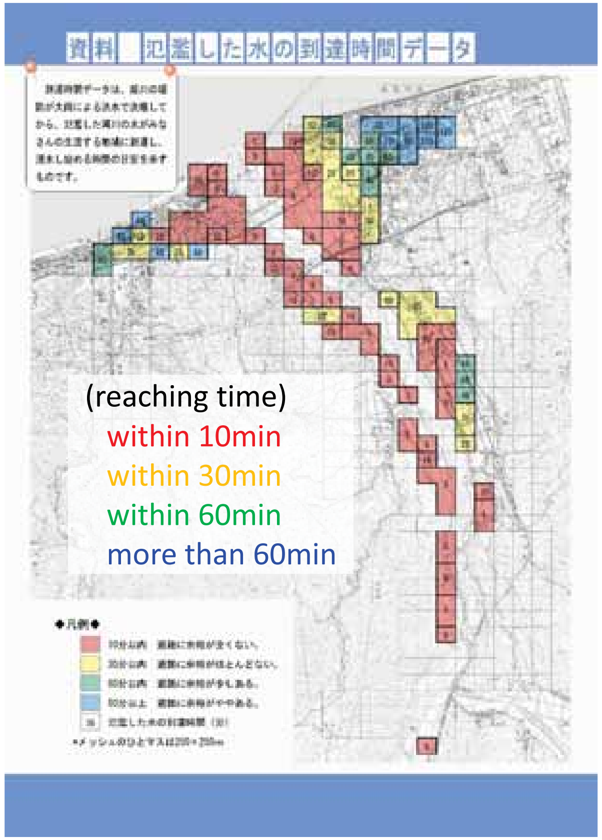
Examples of FHM

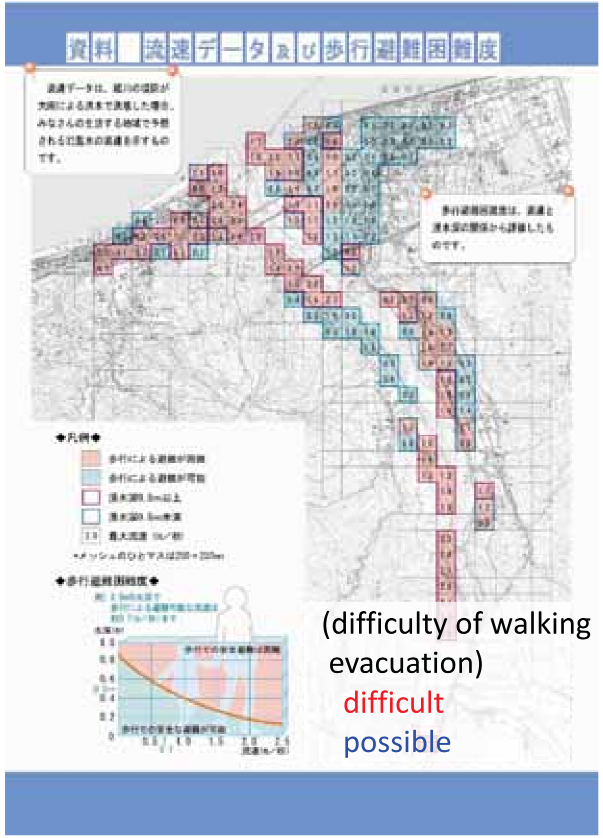
Typical type of FHM; only water depth



(added to Mitoya City HP)

Rare; reaching time and walking difficulty





(added to Itoigawa City HP)

Indexes are independently provided!

Example of conversion to MFHM

Criteria : $I_{C1} = 1.445\text{m}$, $I_{C2} = 45\text{min}$, $I_{C3} = 1.0\text{m/s}$, $I_{C4} = 1.2\text{m}^3/\text{s}^2$

Ex.1 : $I_1 = 1.0\text{m}$, $I_2 = 60\text{min}$, $I_3 = 0.5\text{m/s}$, $I_4 = 0.6\text{m}^3/\text{s}^2$

Ex.2 : $I_1 = 1.0\text{m}$, $I_2 = 60\text{min}$, $I_3 = 1.1\text{m/s}$, $I_4 = 0.6\text{m}^3/\text{s}^2$

① Normalization of parameters

$$\begin{aligned} \boldsymbol{p_n} &= \mathbf{1} - {}^{\boldsymbol{I_n}}/_{\boldsymbol{I_{Cn}}}, \boldsymbol{p_n} \geq \mathbf{0} \\ &= \mathbf{0} \qquad\qquad , \boldsymbol{p_n} < \mathbf{0} \end{aligned}$$

Ex.1

$p_1 = 1 - 1.0/1.445 \approx 0.31$

$p_2 = 1 - (1/60)/(1/45) = 0.25$

$p_3 = 1 - 0.5/1.0 = 0.50$

$p_4 = 1 - 0.6/1.2 = 0.50$

Ex.2

$p_1 = 1 - 1.0/1.445 \approx 0.31$

$p_2 = 1 - (1/60)/(1/45) = 0.25$

$p_3 = 1 - 1.1/1.0 = -0.1 \rightarrow p_3 = 0$

$p_4 = 1 - 0.6/1.2 = 0.50$

② Integration of normalized points

$$\boldsymbol{P'} = (\boldsymbol{p_1} \times \cdots \times \boldsymbol{p_N})^{\mathbf{1}/\boldsymbol{N}}$$

Ex.1: $P' = (0.31 \times 0.25 \times 0.50 \times 0.50)^{1/4} \approx 0.37$

Ex.2: $P' = (0.31 \times 0.25 \times 0 \times 0.50)^{1/4} = 0$

③ Scoring

$$\boldsymbol{P} = \mathbf{100}(\mathbf{1} - \boldsymbol{P'})$$

Ex.1: $P = 100 \times (1 - 0.37) = 63$

Ex.2: $P = 100 \times (1 - 0) = 100$

Procedure to make hydrograph in Mitoya