Applications of Climate Models to Water-related Disaster

Eiichi Nakakita
Disaster Prevention Research Institute
Kyoto University, Japan

DPRI-KU

KAKUSHIN

Innovative Program of Climate Change Projection for the 21st Century
(KAKUSHIN Program)

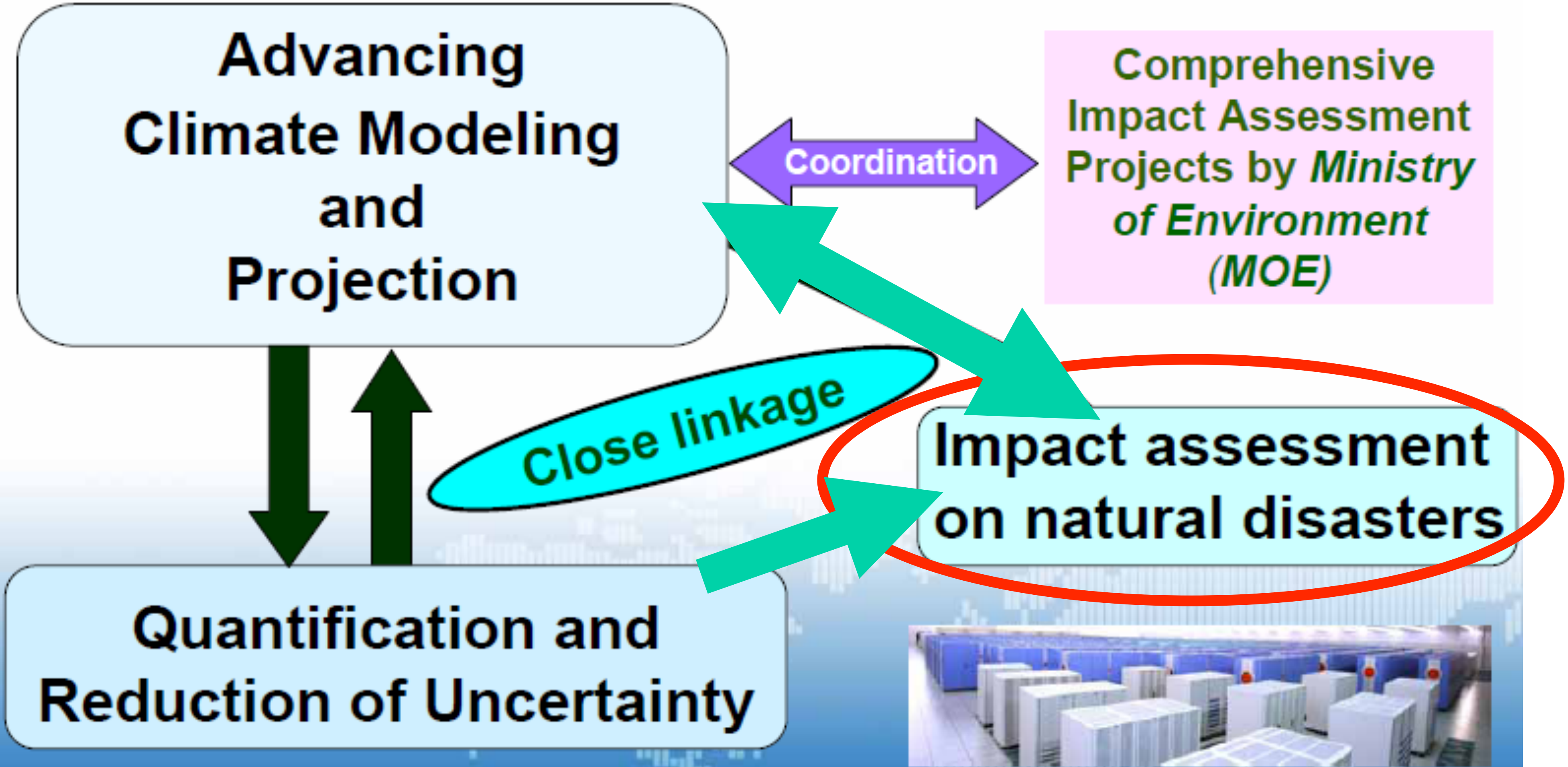
by

Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Secretariat of the Outreach Committee of the Program
Frontier Research Center for Global Change
Japan Agency for Marine-Earth Science and Technology

KAKUSHIN

Program structure



Participating groups and their studies

- ***Long-term global environmental projection***
  with an earth system model
  – Frontier Research Center for Global Change (**FRCGC**) et al.

- ***Near-term climate prediction***
  with a high-resolution coupled ocean-atmosphere GCM
  - Center for Climate System Research (**CCSR**) of the University of Tokyo et al.
  - **Institute of Industrial science (IIS) of the University of Tokyo**

- ***Projection of changes in extremes in the future***
  with super-high resolution atmospheric models
  - Meteorological Research Institute (**MRI**) et al.
  - **Disaster Prevention Research Institute (DPRI) of Kyoto University**
  - **International Centre for Water Hazard and Risk Management (ICHARM Public Work Research Institute (PWRI)) of MLIT**

Estimation of changes in the risk of water-related disasters based on near-term climate prediction with uncertainty considerations

IIS, the University of Tokyo

1. A comprehensive hydrological cycle model for all continents will be dveloped with the spatial resolution of 50km. (MATSIRO + TRIP (developed River Model))
2. The outputs from the high-resolution climate model (MIROC) with 50km spatial resolution will be used as the inputs to the model.
3. Hydrological quantities that are strongly related to water hazards, e.g., river discharge, soil moisture and ground water level, will then be simulated using the hydrological cycle model.
4. The simulation results will be compared with simulation results for the 20th century, and changes in the risk of water-related disasters will be estimated.

KAKUSHIN

Development of River model (TRIP)

- Institute of Industrial science (IIS) of the University of Tokyo

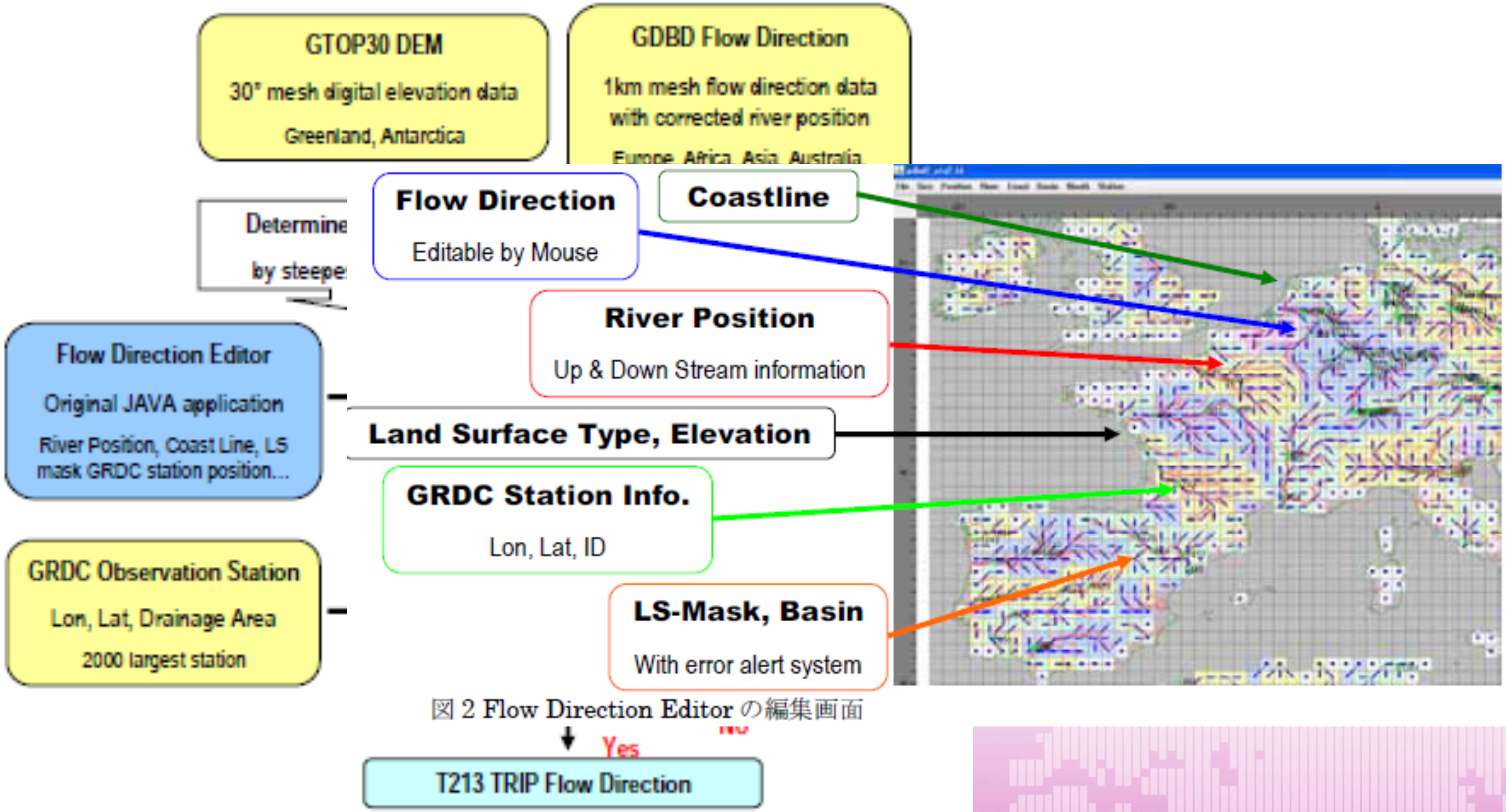
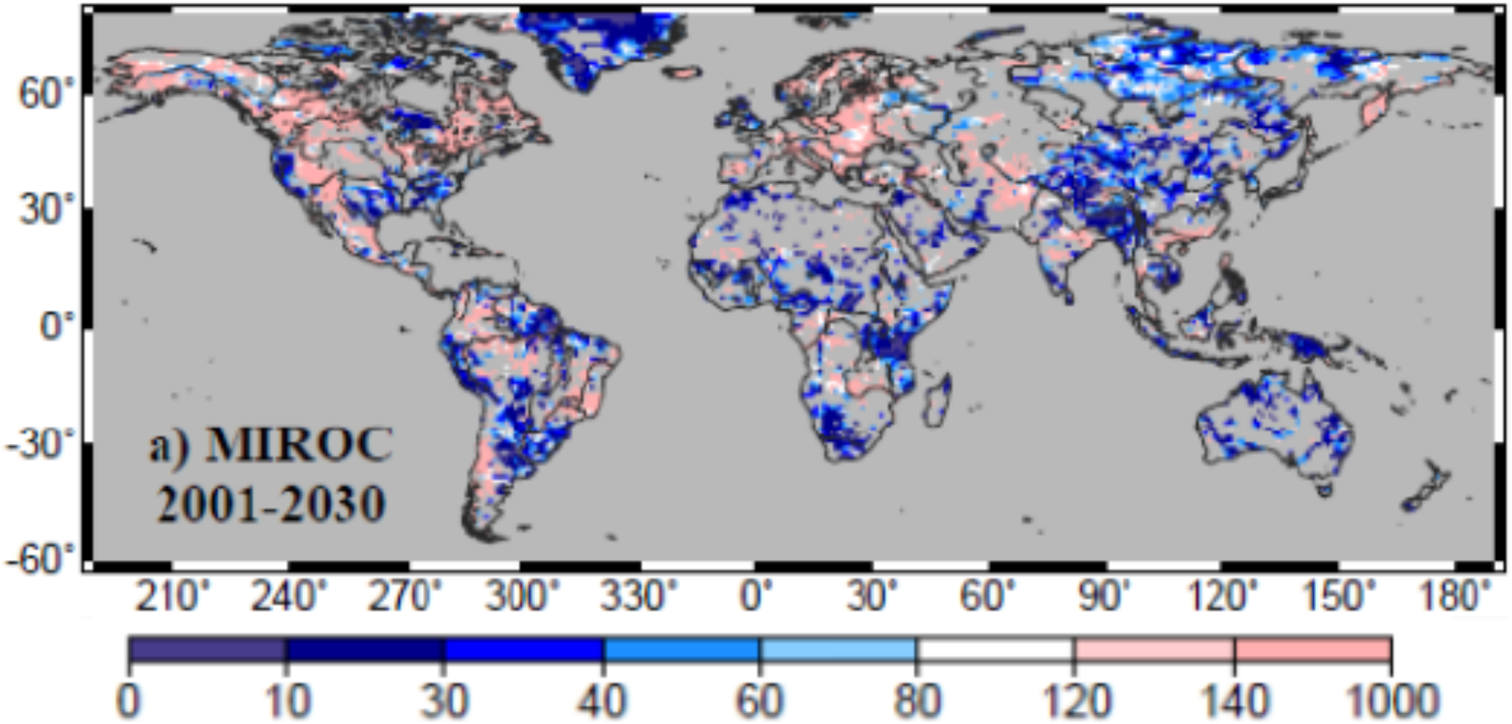


図 2 Flow Direction Editor の編集画面



Projected return period [year] of the 100-year floods in the present-day (1901-2000) simulation during 2001-2030 by MIROC

- Institute of Industrial science (IIS) of the University of Tokyo

Participating groups and their studies

- ***Long-term global environmental projection***

  with an earth system model

  – Frontier Research Center for Global Change (**FRCGC**) et al.

- ***Near-term climate prediction***

  with a high-resolution coupled ocean-atmosphere GCM

  - Center for Climate System Research (**CCSR**) of the University of Tokyo et al.

  - Institute of Industrial science (IIS) of the University of Tokyo

- ***Projection of changes in extremes in the future***

  with super-high resolution atmospheric models

  - Meteorological Research Institute (**MRI**) et al.

  - Disaster Prevention Research Institute (DPRI) of Kyoto University

  - International Centre for Water Hazard and Risk Management (ICHARM Public Work Research Institute (PWRI)) of MLIT

KAKUSHIN

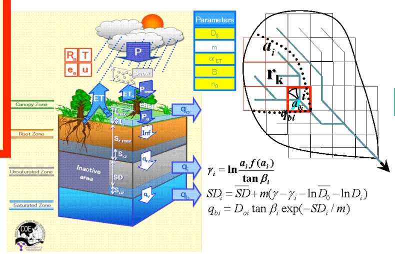
Assessment of climate-change impacts on flood risk and its reduction measures on global and local scales

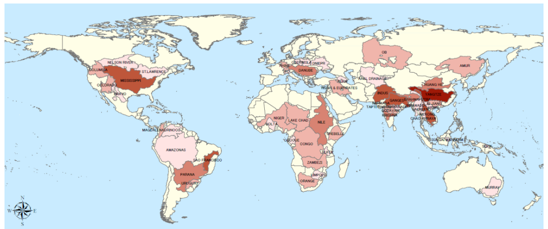
(ICHARM/PWRI)

Global 20km- or 30km-mesh GCM data
from JMA-MRI and Univ.Tokyo-CCSR
(present+near future+21C end)

Evaluation of uncertainty

Block-wise use of TOPMODEL with Muskingum-Cunge method (BTOPMC)





Twelve UNESCO Centres
WMO, IFI, WWAP, ISDR

Reality of flood disaster mitigation measures

World –wide information network through ICHARM, ex) cooperative organizations, JICA experts, etc.

Approaches, methodologies, & tools for ICHARM study

- Relation between GCM outputs & in-situ precipitation
- Hydrologic model for large-scale poorly-gauged basins
  i.e. IFAS-BTOPMC
- Flood inundation evaluation model
- Development of indices to evaluate flood risk & benefit
- Cost-benefit evaluation model to build countermeasures

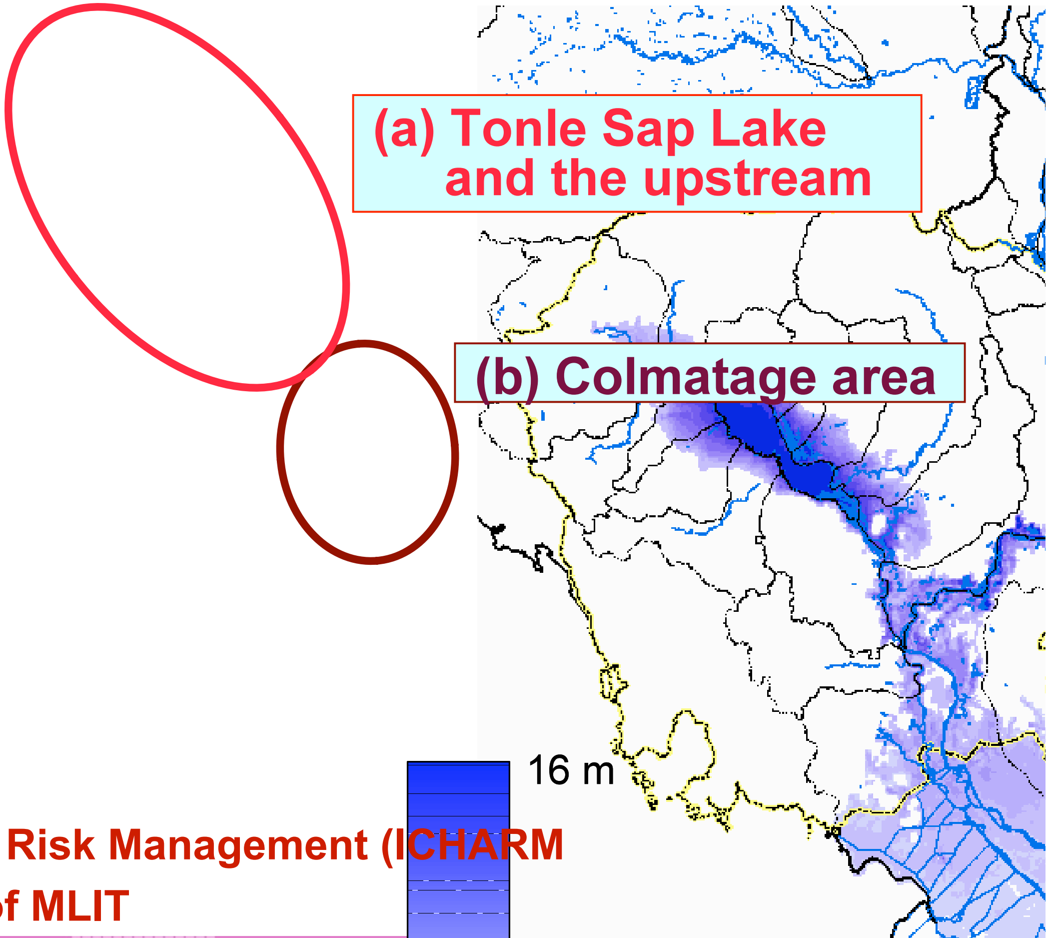
Research outcomes

- Evaluation of uncertainty of extreme rainfall prediction in GCM
- 20-40km- (global) or 1km- (specific local) mesh flood risk map
- Indices to evaluate flood risk & benefit
- Scenarios of flood risk reduction measures on a global scale
- Local case-studies on flood risk reduction in specific vulnerable areas

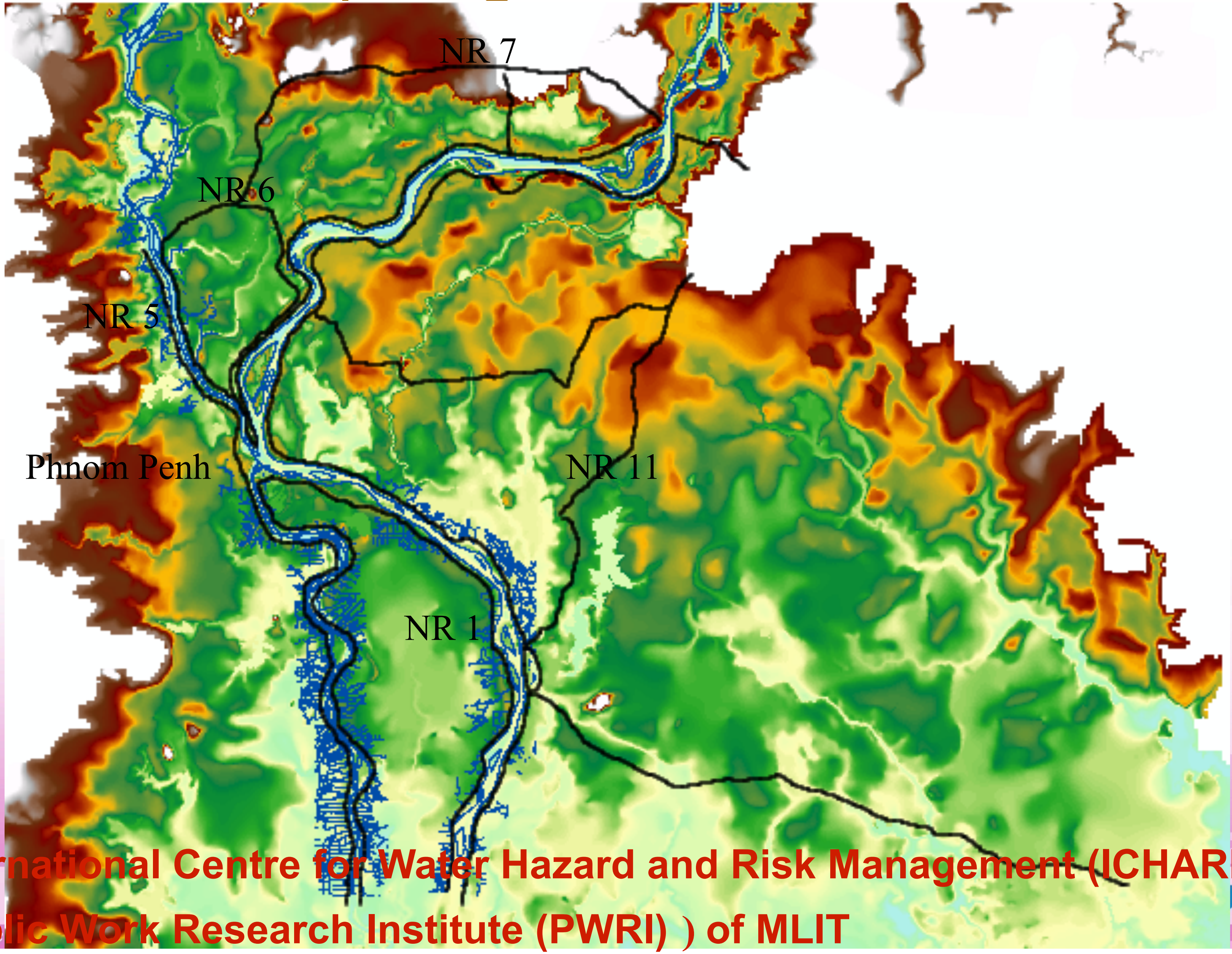
3rd World Water Development Report, 5th IPCC report

Estimation of Flooded Water on Paddies

i) Use simulated results of maximum flood extent of the years 2000 & 2003 are the representatives of recent largest flood and drought years.
ii) Imported the maximum inundated areas and water depths of the years by overlaid simulated results on <u>1,000m grid of land-use</u> data.

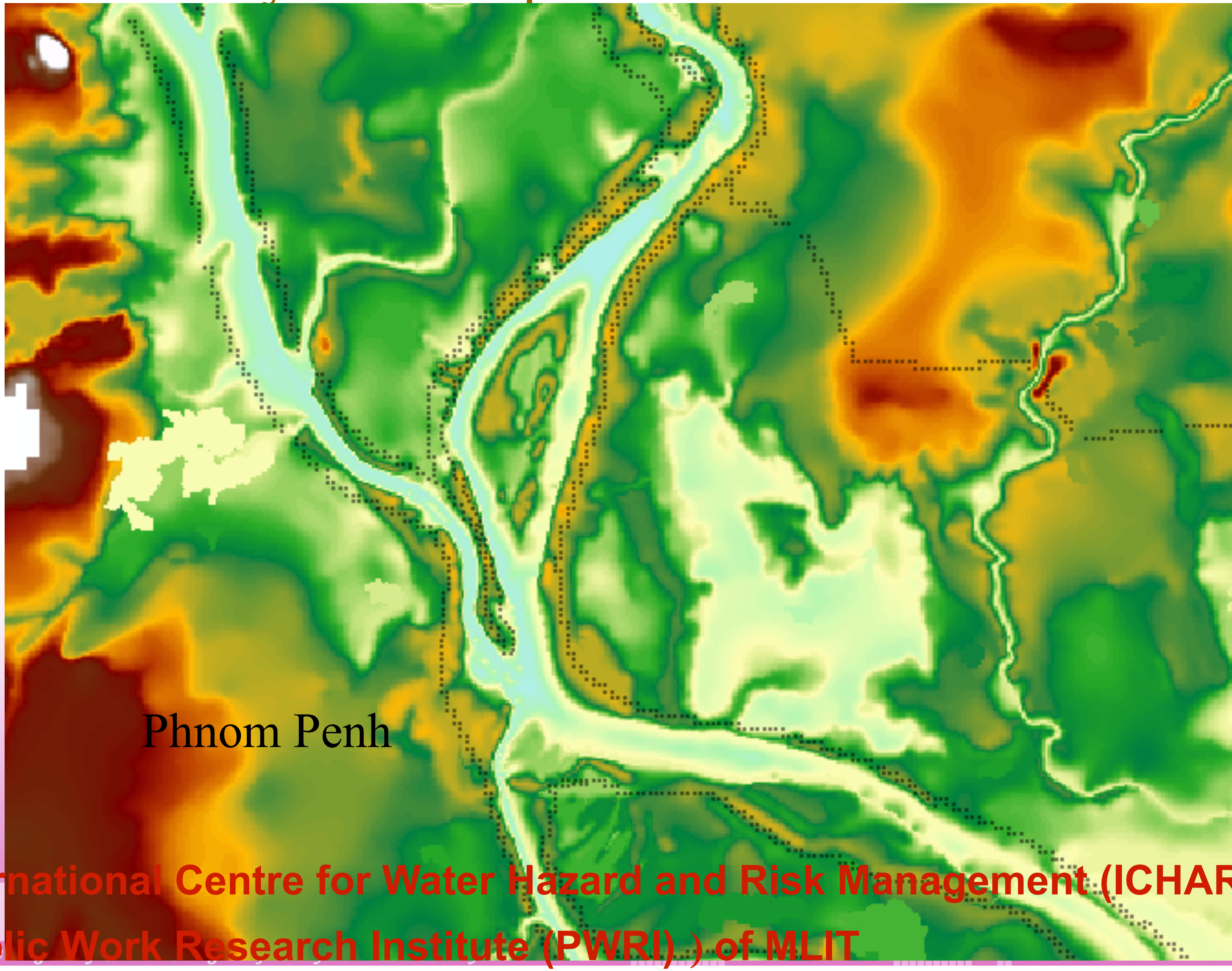


Introduction of main Roads, Dikes & Road-opening Works in the Simulation



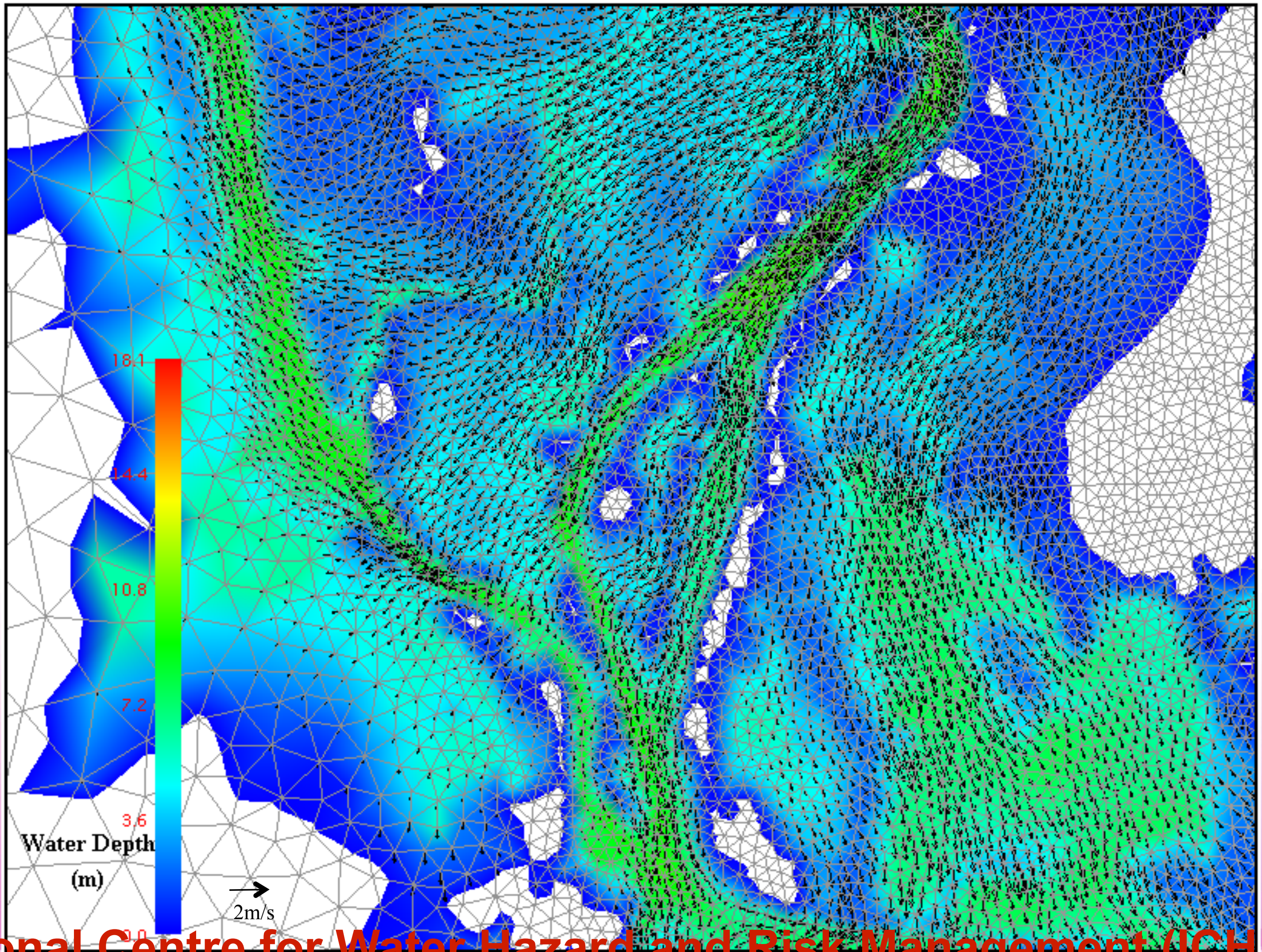
-International Centre for Water Hazard and Risk Management (ICHARM
Public Work Research Institute (PWRI)) of MLIT

Conversion of Roads, Dikes & Road-opening Works' Poly-line-shape data to Points data



-International Centre for Water Hazard and Risk Management (ICHARM
Public Work Research Institute (PWRI)) of MLIT

Simulated flow field at the confluence of Tonle Sap & Mekong rivers on Sep. 1st, 2000



-International Centre for Water Hazard and Risk Management (ICHARM
Public Work Research Institute (PWRI)) of MLIT

Participating groups and their studies

- ***Long-term global environmental projection***

  with an earth system model

  – Frontier Research Center for Global Change (**FRCGC**) et al.

- ***Near-term climate prediction***

  with a high-resolution coupled ocean-atmosphere GCM

  - Center for Climate System Research (**CCSR**) of the University of Tokyo et al.

  - Institute of Industrial science (IIS) of the University of Tokyo

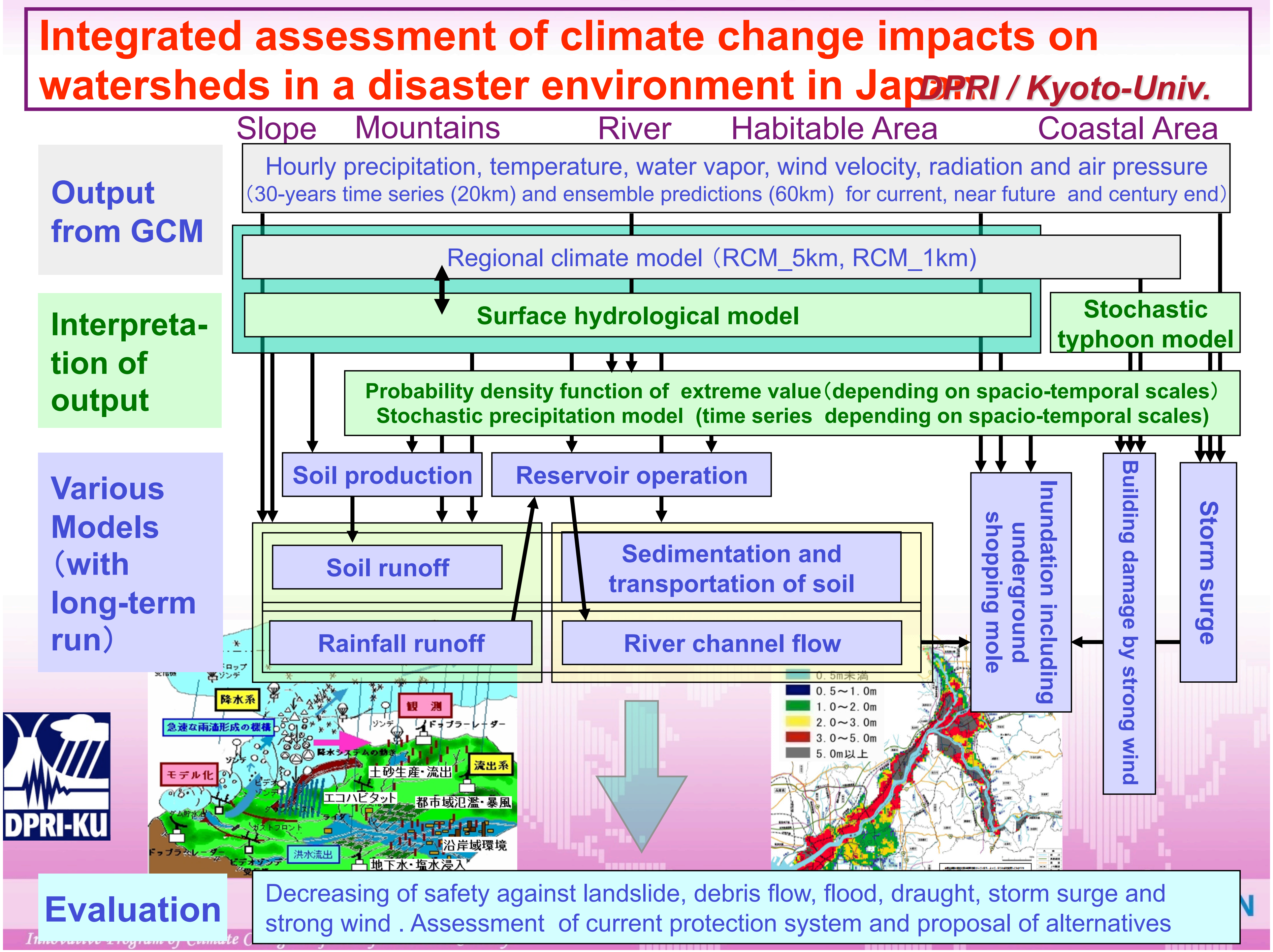
- ***Projection of changes in extremes in the future***

  with super-high resolution atmospheric models

  - Meteorological Research Institute (**MRI**) et al.

  - Disaster Prevention Research Institute (DPRI) of Kyoto University

  - International Centre for Water Hazard and Risk Management (ICHARM Public Work Research Institute (PWRI)) of MLIT


Integrated assessment of climate change impacts on watersheds in a disaster environment in Japan
DPRI / Kyoto-Univ.
Slope
Mountains
River
Habitable Area
Coastal Area
Output from GCM
Hourly precipitation, temperature, water vapor, wind velocity, radiation and air pressure
（30-years time series (20km) and ensemble predictions (60km) for current, near future and century end）
Interpreta-tion of output
Regional climate model（RCM_5km, RCM_1km)
Surface hydrological model
Stochastic typhoon model
Probability density function of extreme value（depending on spacio-temporal scales）
Stochastic precipitation model (time series depending on spacio-temporal scales)
Various Models（with long-term run）
Soil production
Reservoir operation
Soil runoff
Sedimentation and transportation of soil
Rainfall runoff
River channel flow
Inundation including underground shopping mole
Building damage by strong wind
Storm surge
降水系
観 測
急速な雨滴形成の機構
モデル化
流出系
降水システムの動き
土砂生産･流出
エコハビタット
都市域氾濫･暴風
沿岸域環境
洪水流出
地下水･塩水浸入
0.5m未満
0.5～1.0m
1.0～2.0m
2.0～3.0m
3.0～5.0m
5.0m以上
DPRI-KU
Evaluation
Decreasing of safety against landslide, debris flow, flood, draught, storm surge and strong wind . Assessment of current protection system and proposal of alternatives

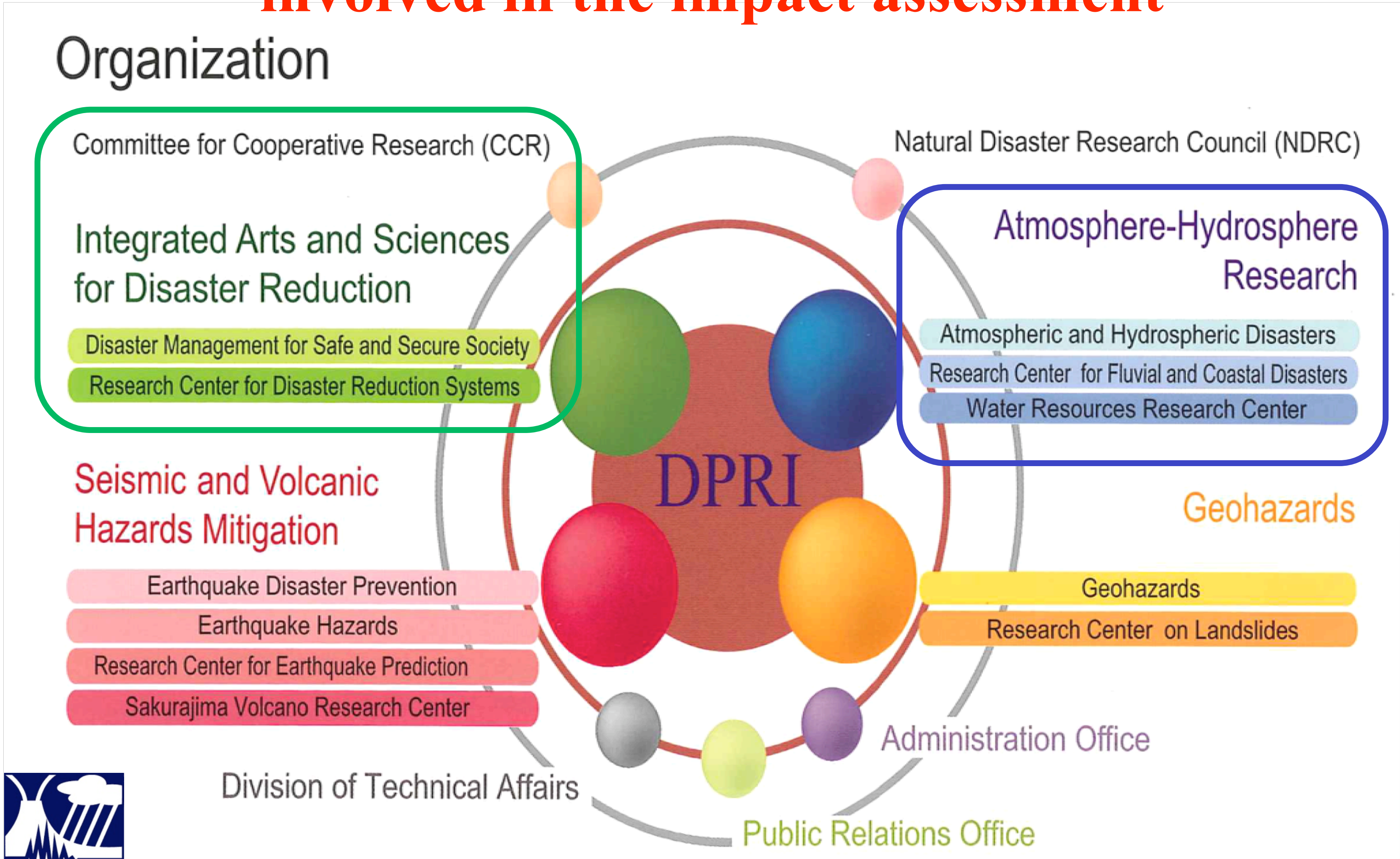
Minimum Target of DPRI

- Interpletation of GCM output
- Precipitation: Global
- Land slide and Debris flow: mainly western Japan
- River discharge:
  Japanese main large river basins (with fine resolution)
  All Japanese river basins (with medium resolution)
- Storm surge: Tokyo, Ise (Nagaya) and Osaka Bays
- Damage by strong wind: entire Japanese archipelago
- Inundation: Tokyo, Nagoya, Osaka and Fukuoka

DPRI-KU

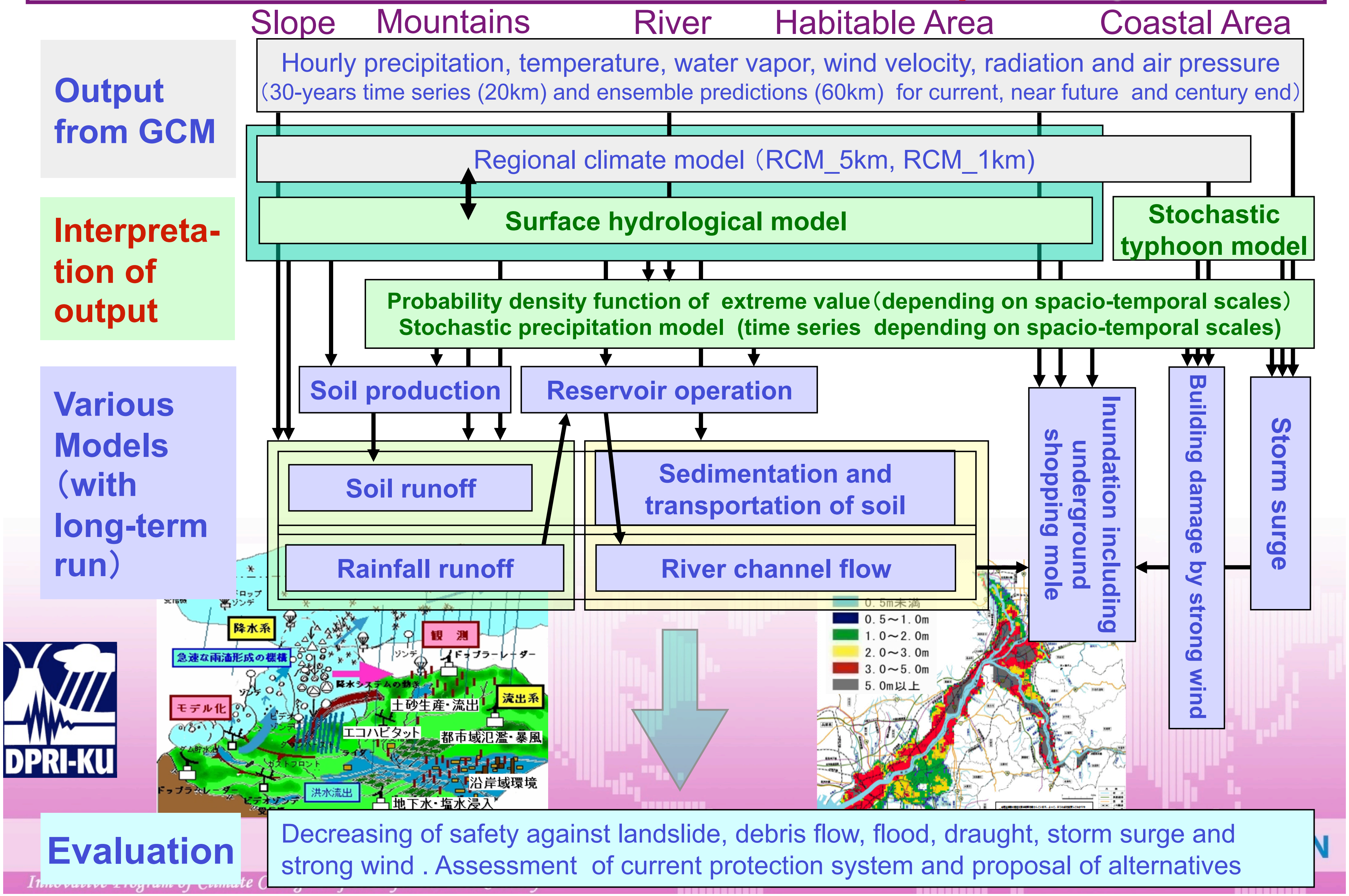
KAKUSHIN

Research division and center in DPRI involved in the impact assessment



Integrated assessment of climate change impacts on watersheds in a disaster environment in Japan

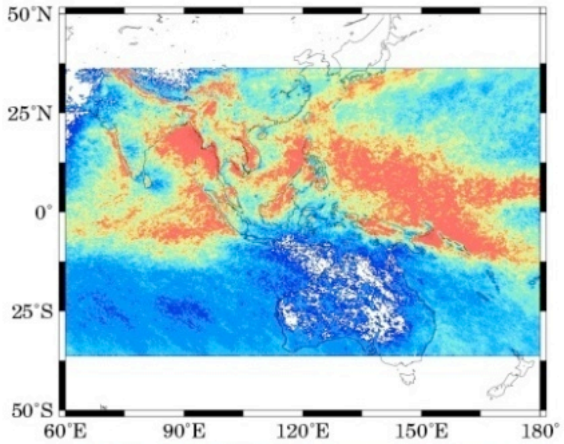
DPRI / Kyoto-Univ.



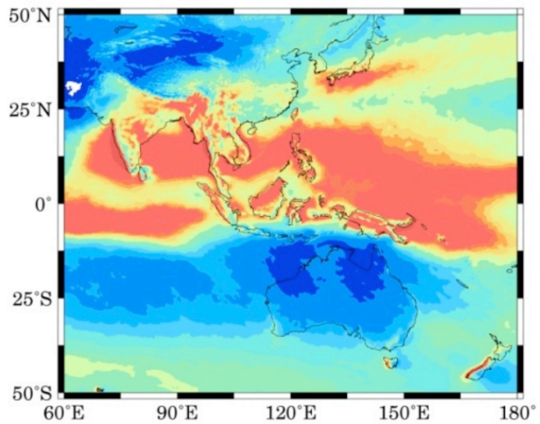
Difference Between GCM Output and TRMM Satellite Observations

June-October

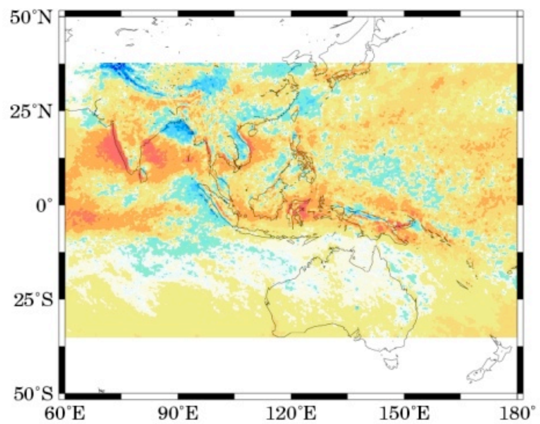
Monthly Mean Rainfall（30 month average）



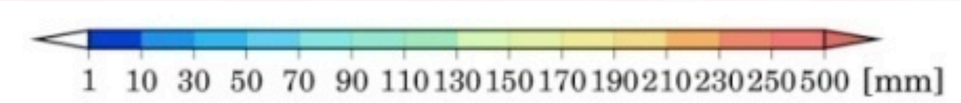
TMI2A12 (2002-2007)



GCM(1999-2004)



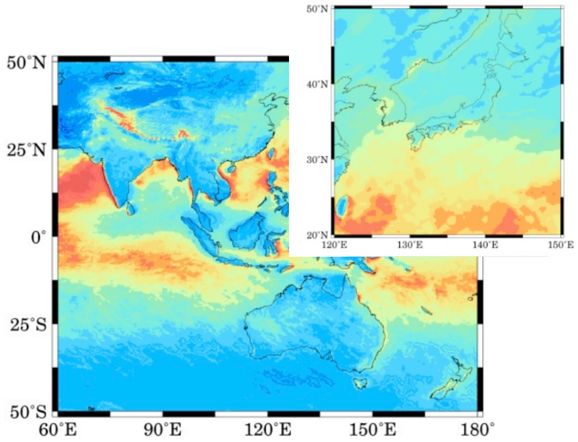
GCM(Present)-TMI



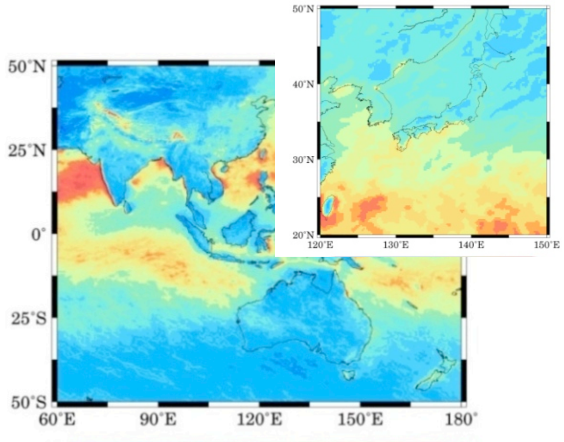
By Nakkaita and Konoshima (2008)

Estimated Temporal Correlation Length from GCM of Instantaneous Rainfall

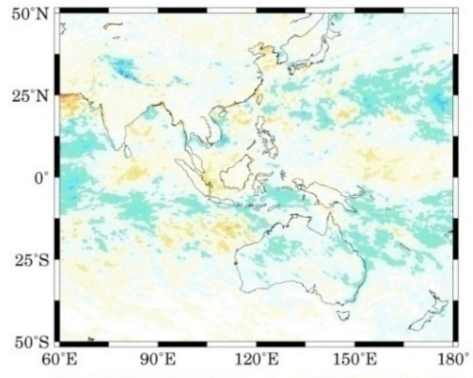
June-October



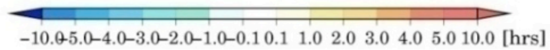
Present (1979-2004)



Future (2067-2100)

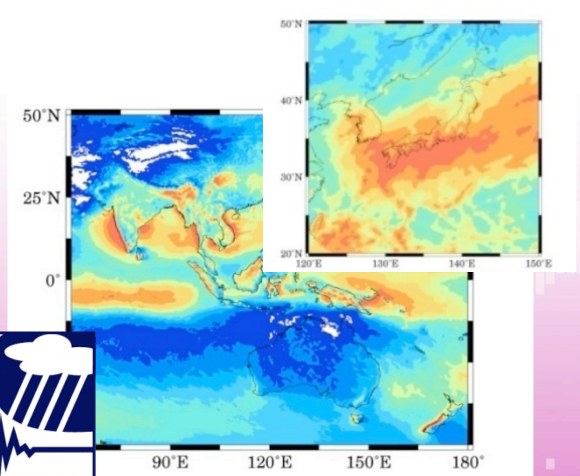


Future-Present

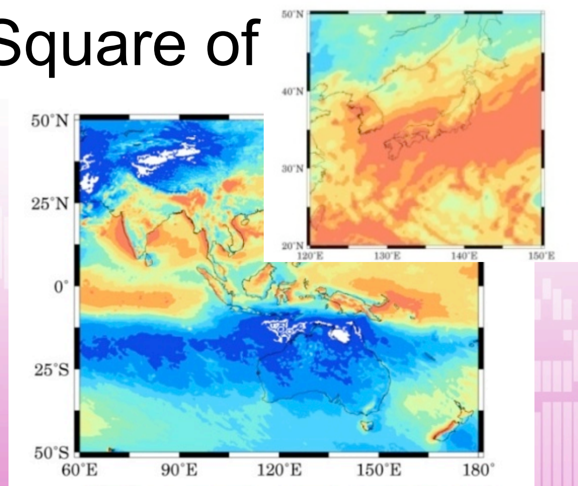


Square of

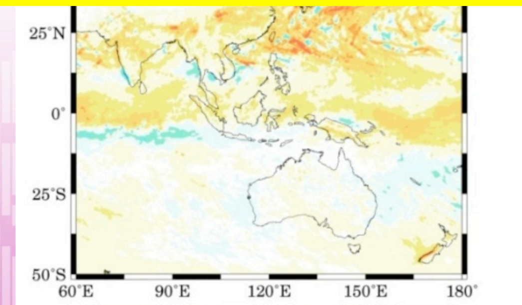
The future rainfall changes to shorter range, higher intensity rainfall



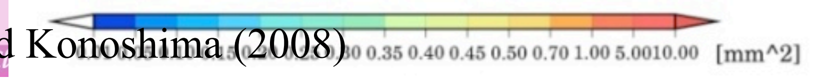
Present (1979-2004)

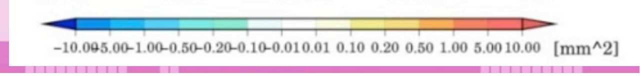


Future



Future-Present



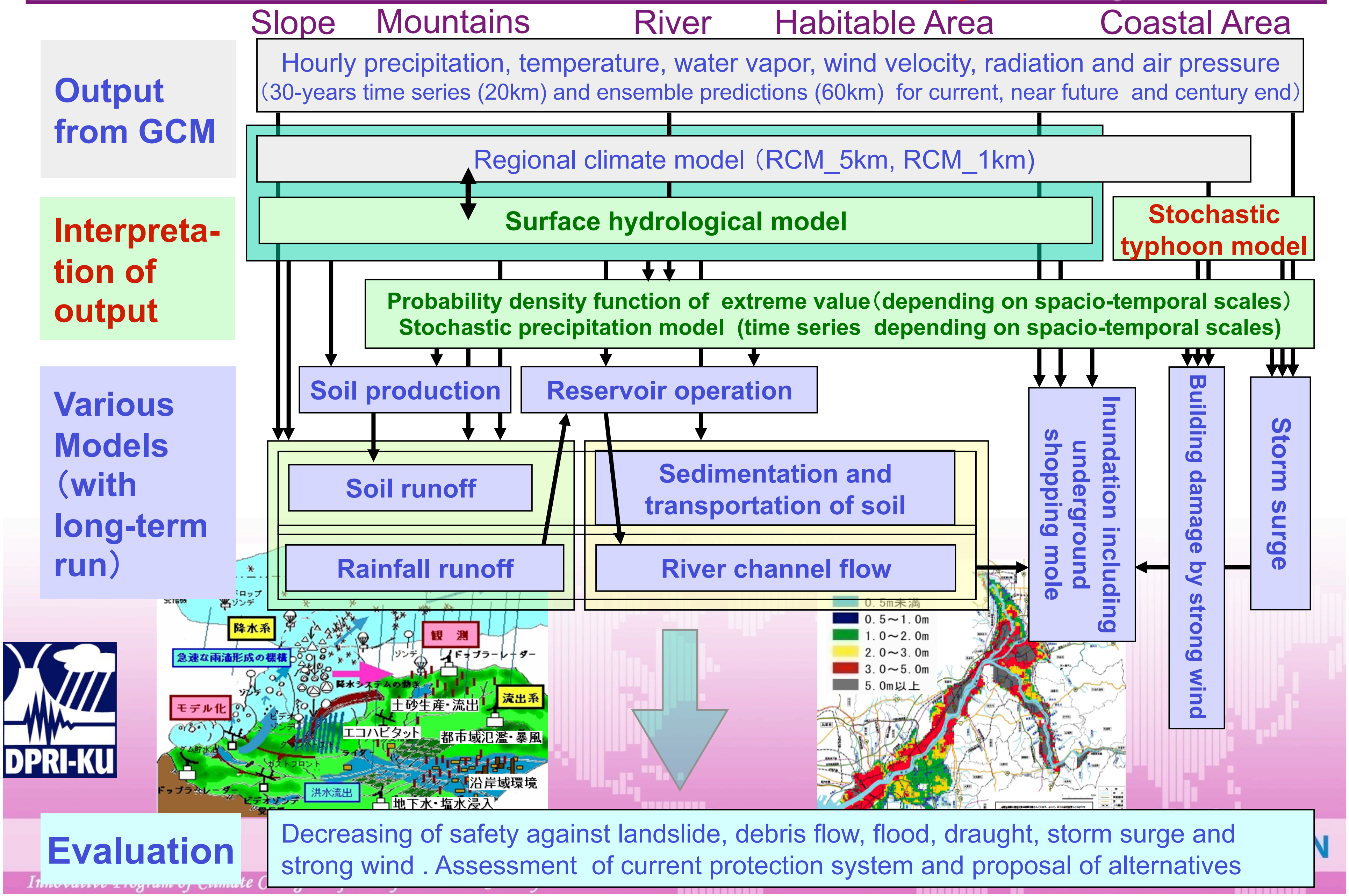


By Nakkaita and Konoshima (2008)

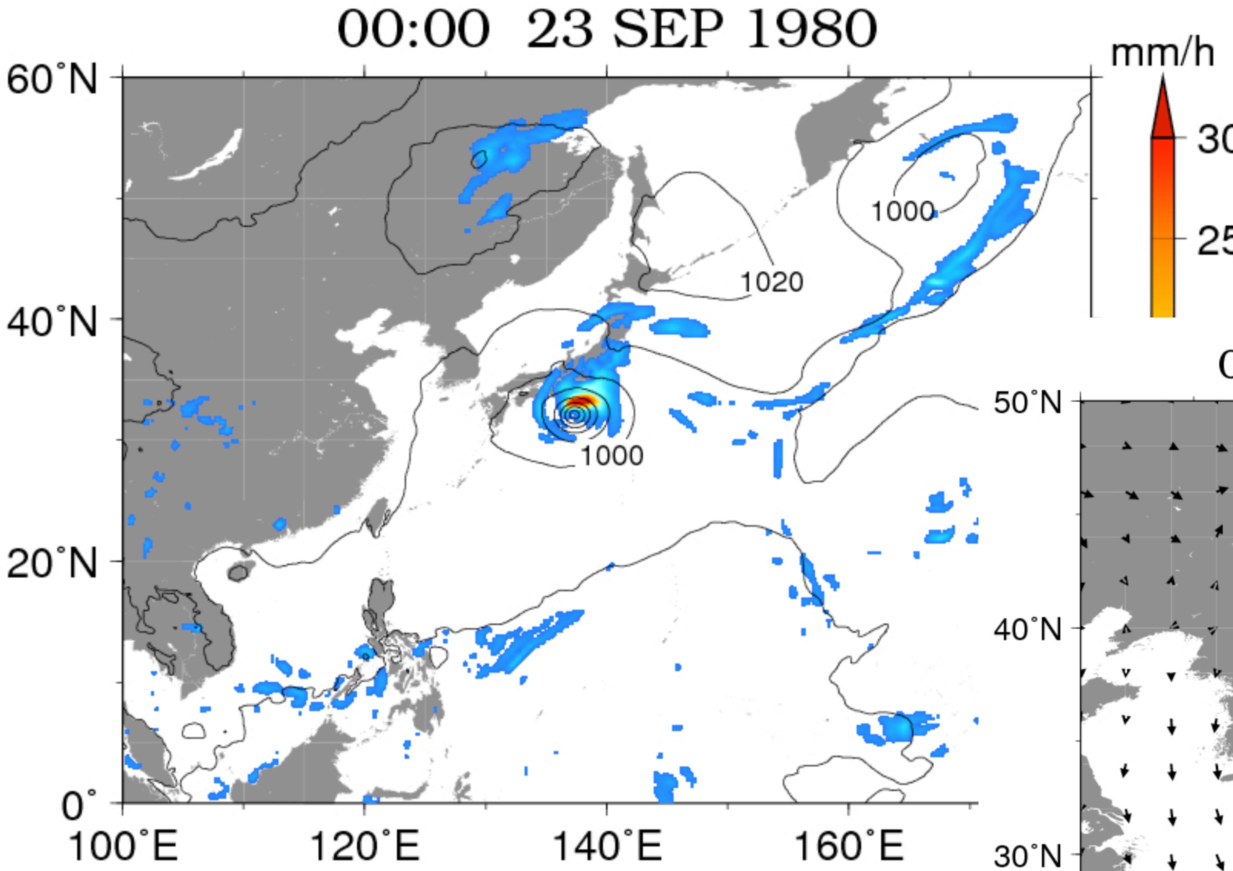
DPRI-KU

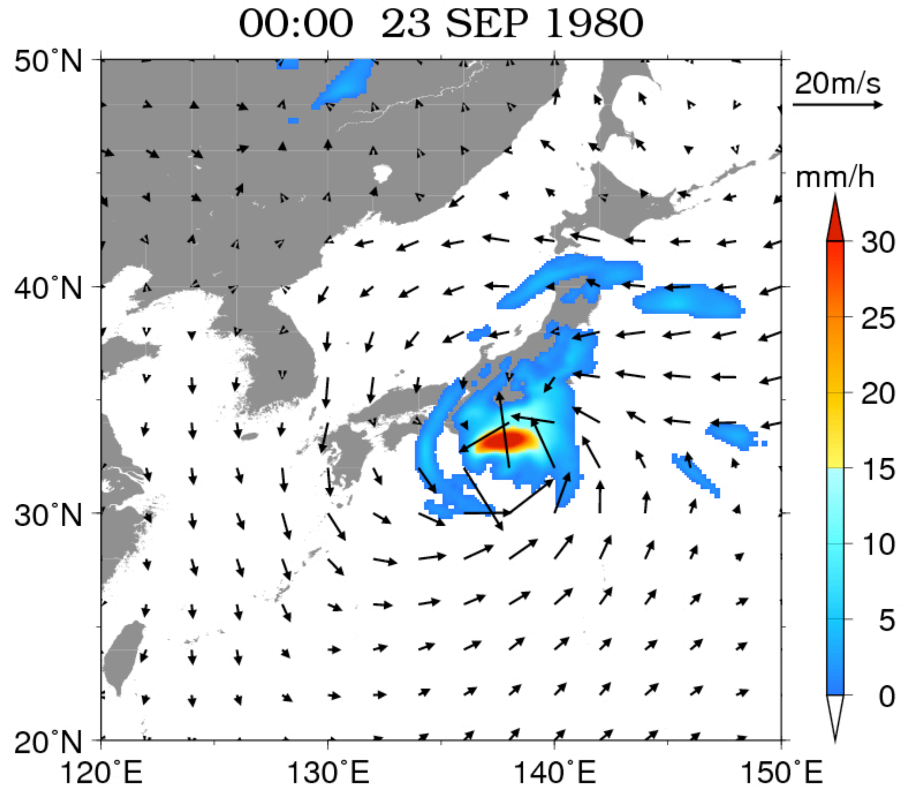
Integrated assessment of climate change impacts on watersheds in a disaster environment in Japan

DPRI / Kyoto-Univ.



Typhoon by 20km-GCM

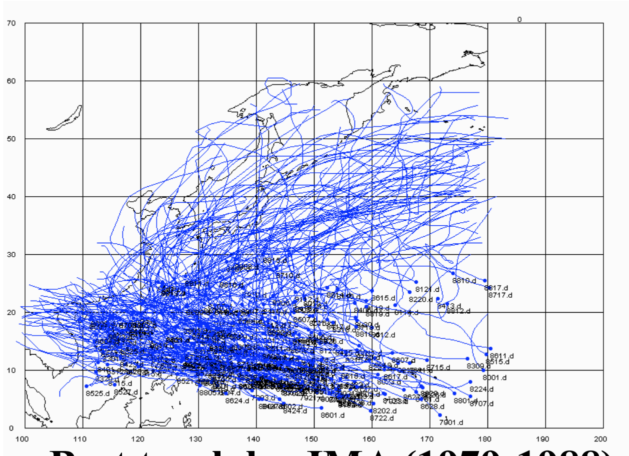




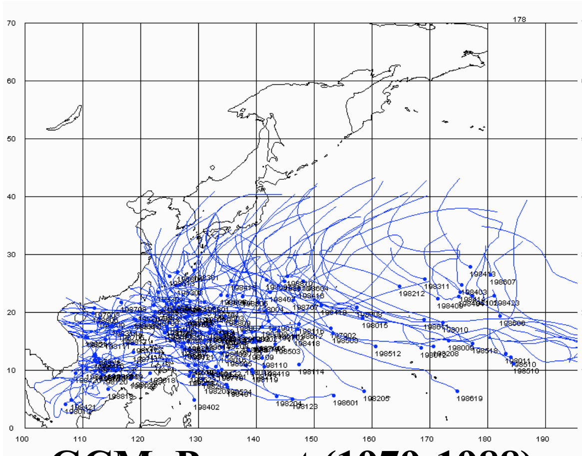
It is the typhoon resolving output that has realized the impact assessment of Japanese disasters

By MRI (2008)

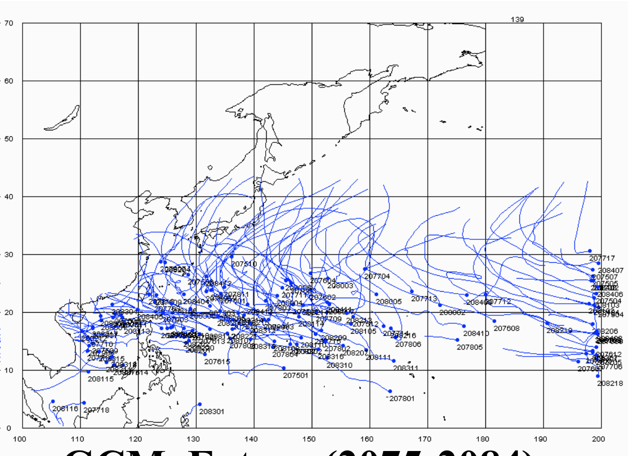
Comparison of typhoon track



Best track by JMA (1979-1988)



GCM_Present (1979-1988)



GCM_Future (2075-2084)

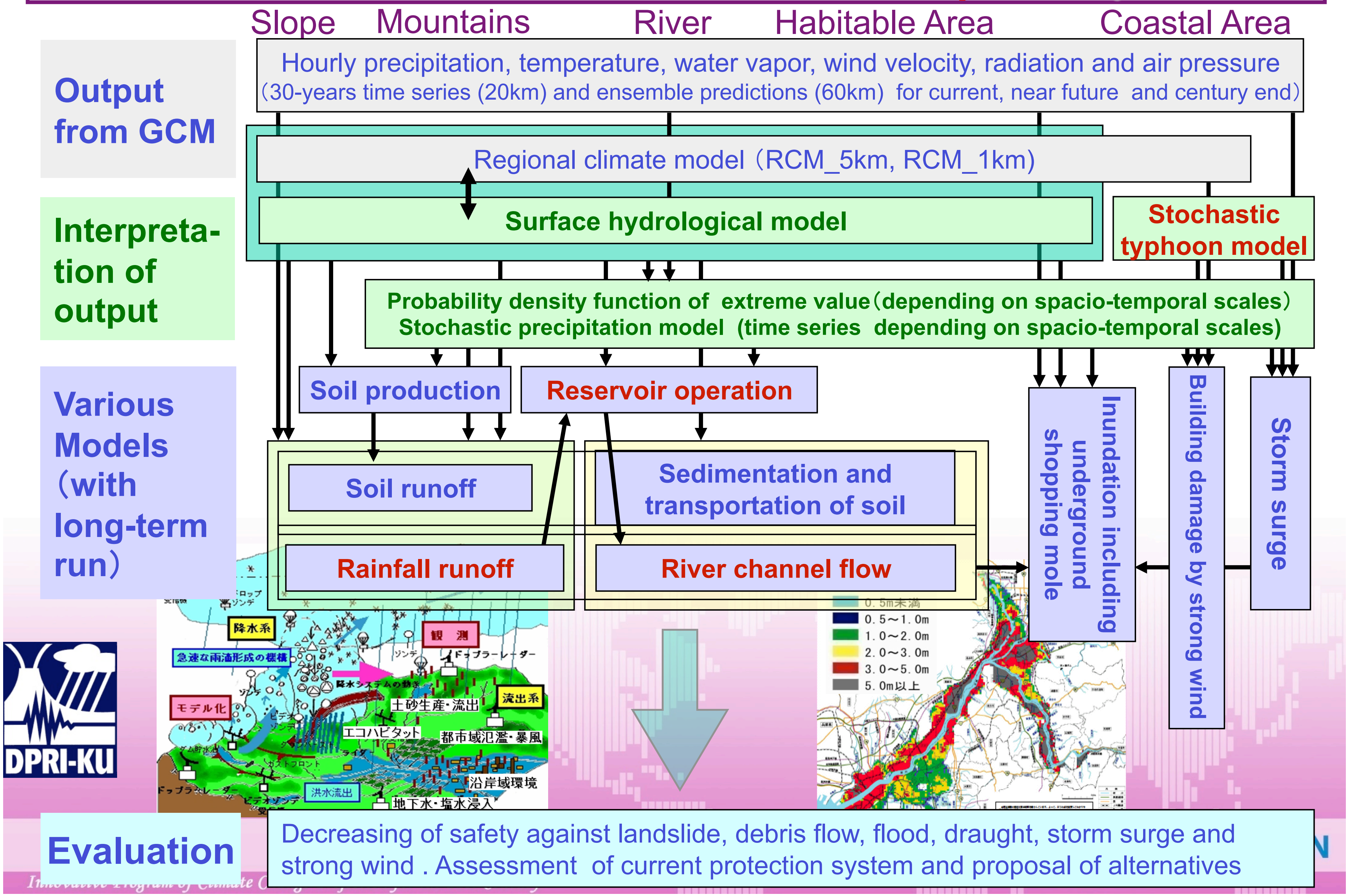
- Region of generation will move Northward by 2.6 degree.
- The number of typhoon approaching Japan will increase.
- The number of generation in the "GCM_Present" is much smaller than that of current observation.

DPRI-KU

By Mase et al. (2008)

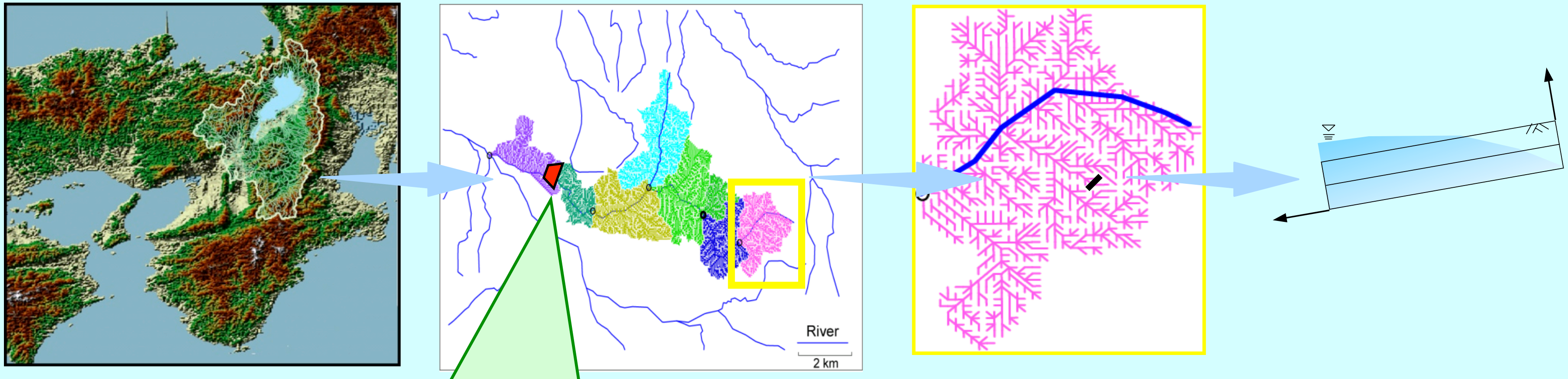
Integrated assessment of climate change impacts on watersheds in a disaster environment in Japan

DPRI / Kyoto-Univ.

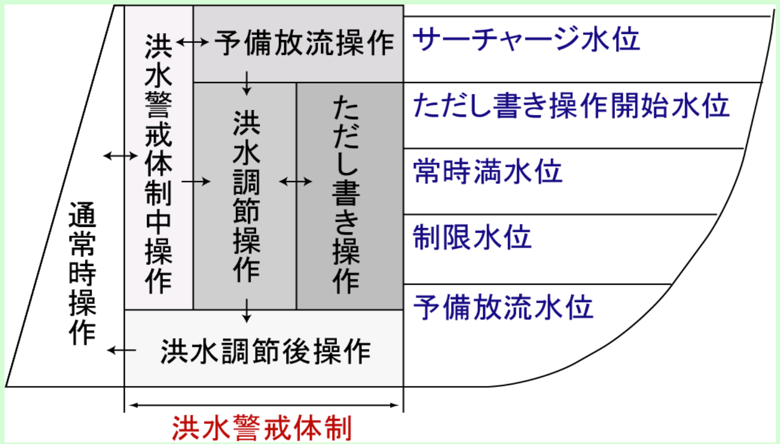


Introducing reservoir operation models into distributed runoff model

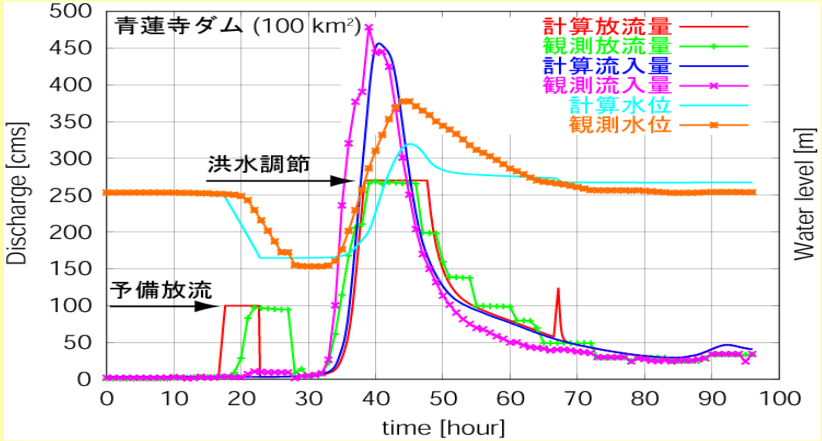
System of distributed runoff model



Reservoir operation model

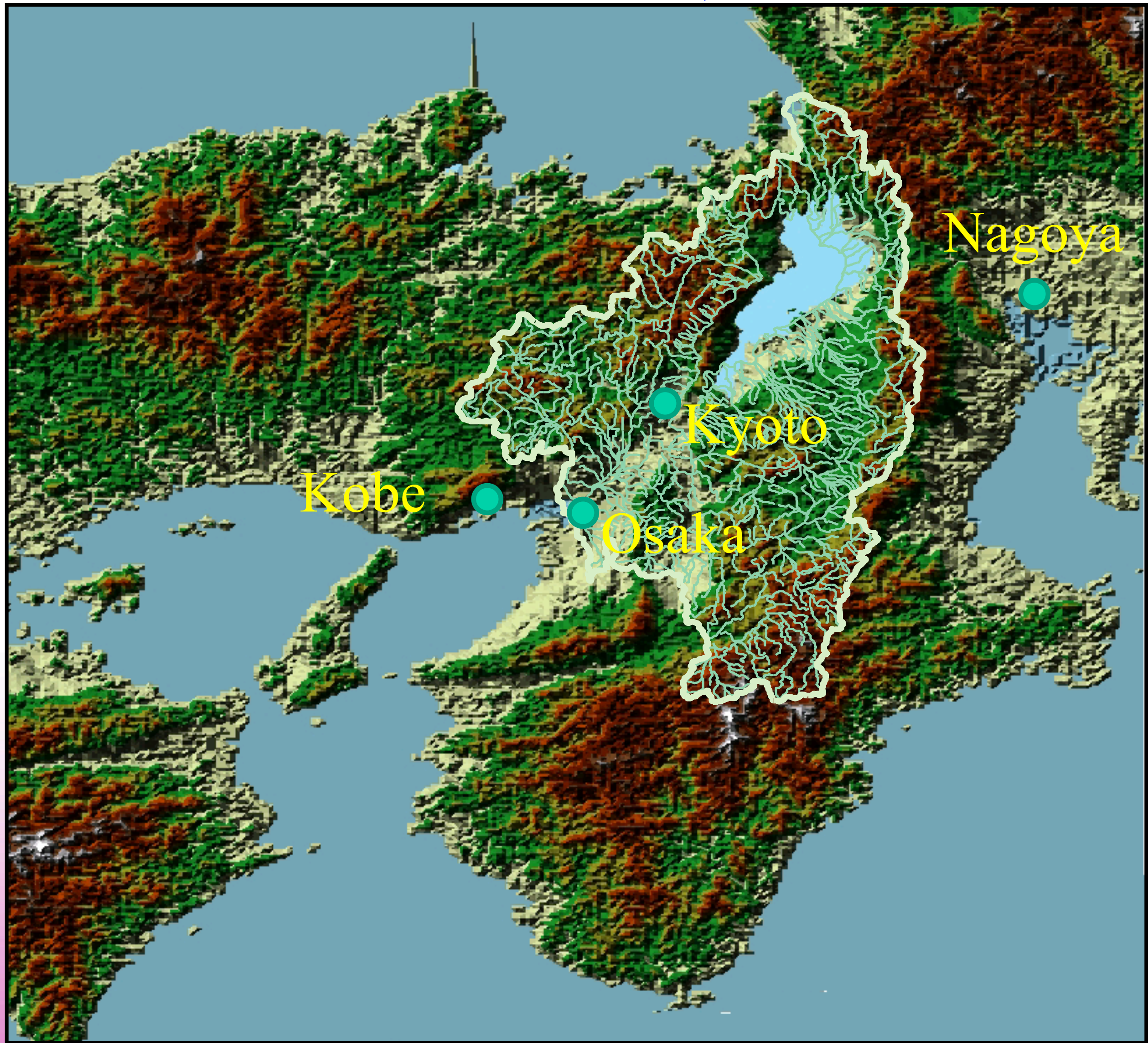


Example of combined computation

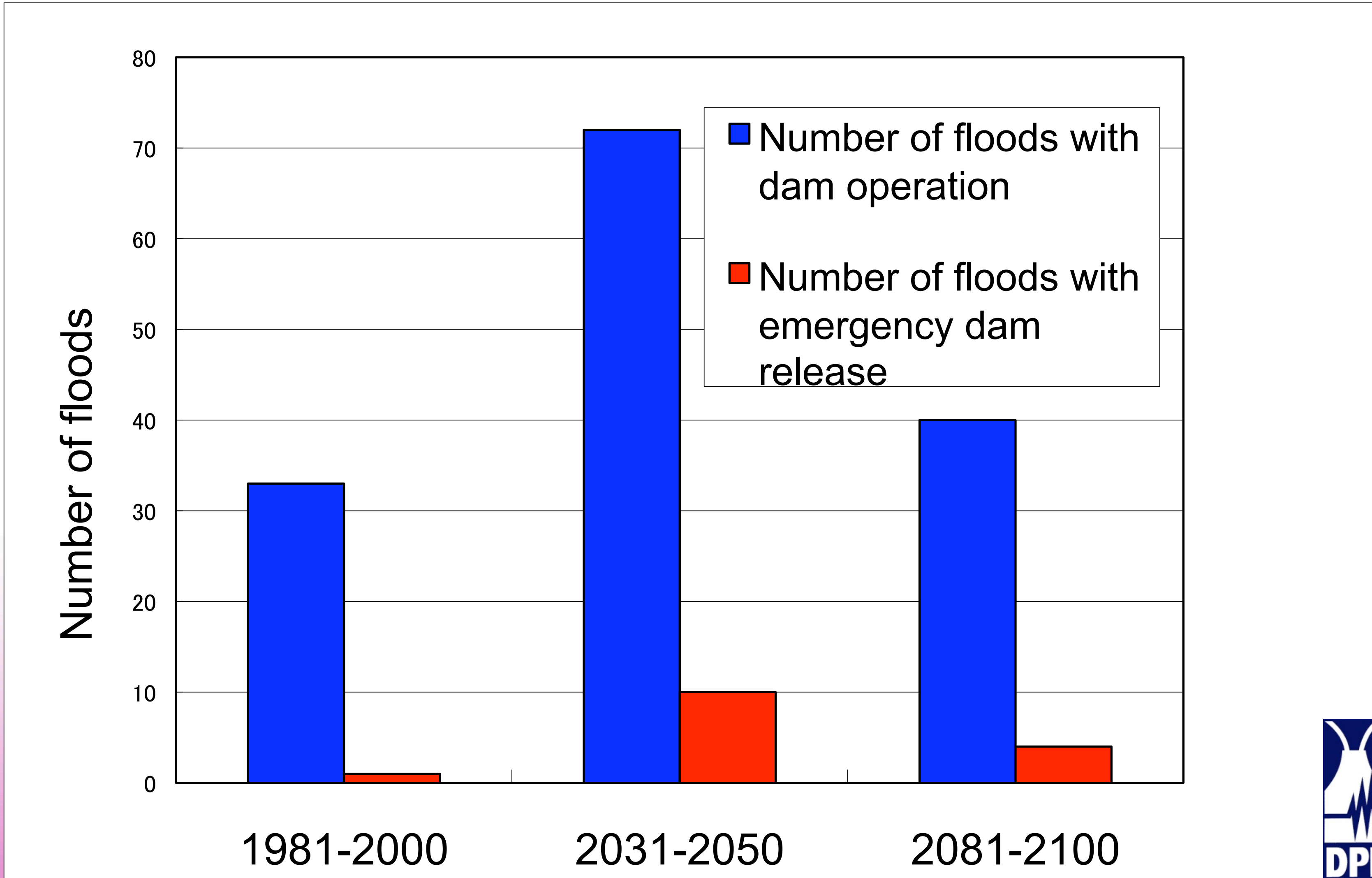


By Sayama et al. (2007)

Pilot study using a distributed runoff Model (eg. Yodo River basin; 7,281km²)

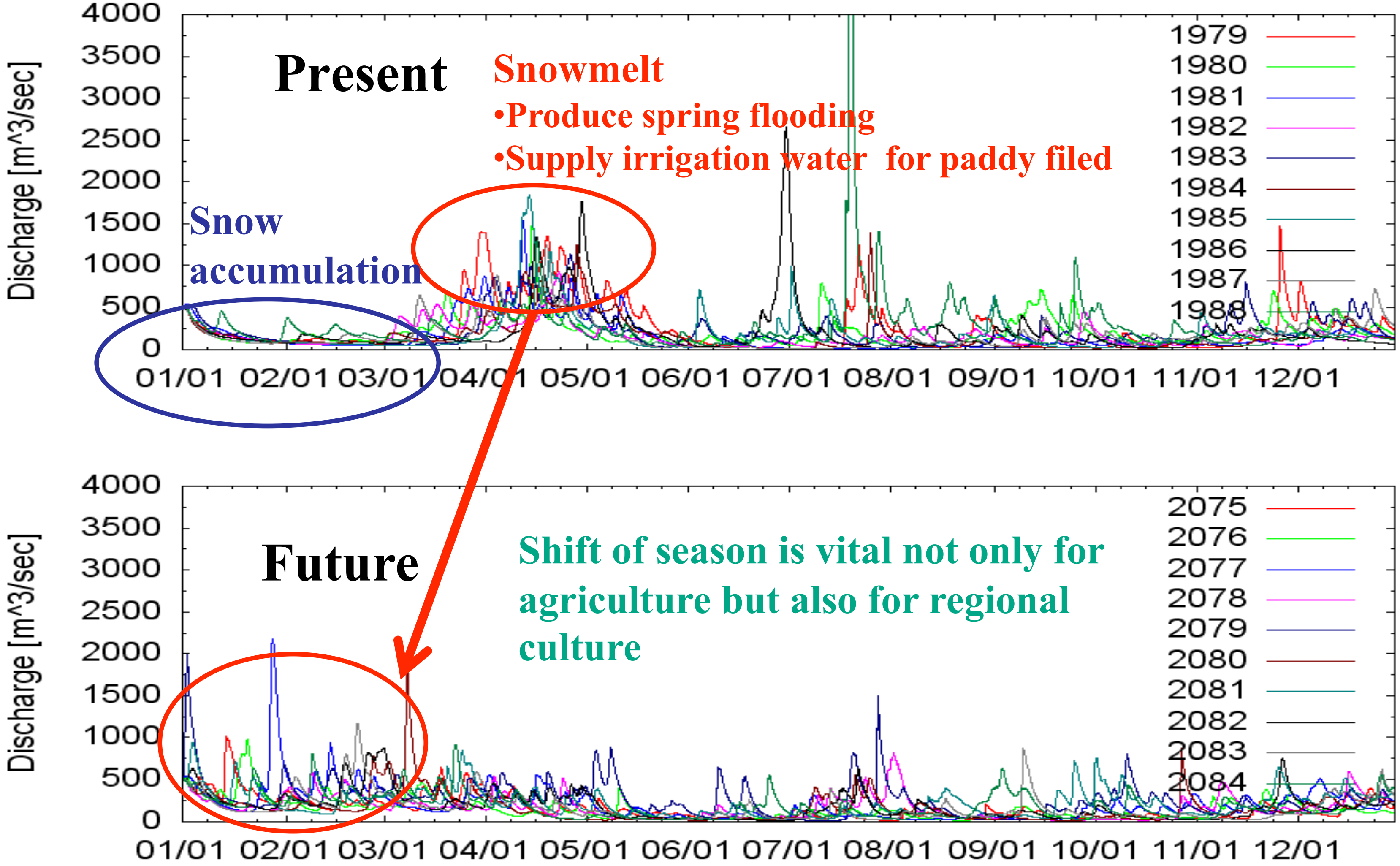


Possible changes in the number of floods requiring dam operation and emergency dam release



By Sayama et al. (2007)

Influence of changing in snowfall and snow melt (Mogami River)

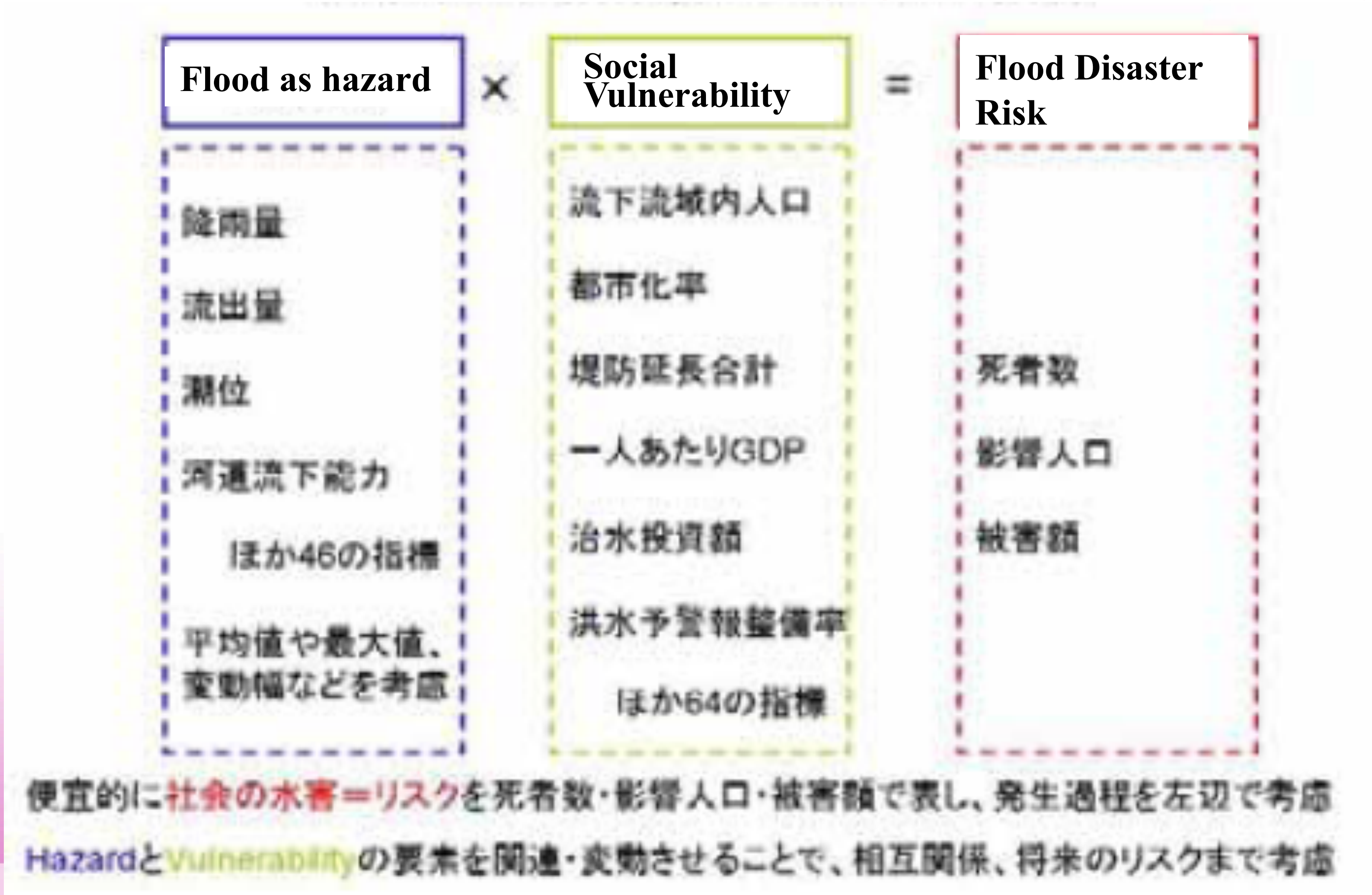


By Tachikawa et al. (2008)

Towards the Risk Assessments

Estimation of Flood Risk

- Institute of Industrial science (IIS) of the University of Tokyo



Flood Disaster Risk Index R=HxVxE/C

「災害リスク(Disaster Risk)」

- (HD)人的被害(死者、被害者、避難者)、
- (EecD)経済的被害
- (Gd)動産(家財、商品、生産財、農林水産物、エネルギー・食糧等備蓄、文化財)、
- (Prp)不動産(建築物、公共インフラ、景観)、
- (Liv)生活・生産活動(営業、交通、ライフライン等サービス)
- (EnvD)環境破壊、汚染
- (Dta)被害期間、被害地域

「自然の猛威(Natural Hazard)」

- (MID)規模、強度、継続時間、
- (F)頻度、
- (Htp)発生地点、発生時期、
- (HI)人工的増幅要因(森林伐採、斜面開発等)
- (HM)緩和手段:人工降雨、

「社会の災害脆弱性(Societal Vulnerability)」(社会の基礎体力の弱さ)

- (Pov)貧困(GDP, EVI(経済脆弱性指標))
- (G)ガバナンス(説明責任、政情の安定、行政効率、規則順守、法規制、賄賂統制)
- (Hel)健康(栄養状態、身障者・病人割合)
- (Dem)年齢構成(幼児、妊婦、後期高齢者割合)
- (Ed)教育水準(非識字率、IT文盲率)
- (W)日常的弱者支援・救済体制、不法居住者支援体制
- (SC)近隣コミュニティーの相互扶助能力(Social Capacity)

「暴露(Exposure)」

- (RA)危険地域(活断層帯、噴火影響地帯、洪水氾濫原、急傾斜地、地滑り地帯、ゼロメータ地帯、埋立地等)の危険度別面積、
- (P&A)危険地域の居住人口、人口密度、経済活動集中度、
- (LUC)土地利用計画(産業配置、湛水許容地区)、規制、誘導策(税制、補助金、)

「防災能力(Coping Capacity)」

- (St)構造物型インフラ:免震設計、ダム、堤防、放水路、砂防工事、貯留浸透施設、ピロティー式家屋
- (NSt)非構造物型インフラ:
- (Prep)準備体制(危険度評価、ハザードマップ・利用体制、
- (EW)予警報(観測網、データ伝送・処理体制、予測技術、伝達メディア)、予警報研究、
- (ER)避難体制、避難生活支援、復旧、救援ボランティア
- (I)制度・組織インフラ:中央防災体制、地域防災体制、緊急対応自治組織(水防団、消防団)、
- (F)予算:防災予算、緊急対応予算、復旧予算、海外援助資金、防災科学予算
- (CET)防災文化・教育・訓練:社会的防災伝承、小・中学防災教育、地学教育、マルチハザード防災訓練

Risk Assessment on Natural Disaster

- Disaster Prevention Research Institute (DPRI) of Kyoto University

Disaster abnormality (Risk: $R_{D,S}$) due to abnormal meteorological forcing

$$= \text{Abnormality of Forcing } (F_{D,S}) \times \frac{1}{\text{Natural Coping } (NCP_{D,S})} \times \frac{1}{\text{Social Coping } (SCP_{D,S})}$$

D: duration of forcing event

S: Spatial scale of forcing event

By Nakakita (2008)

What is the impact assessment and adaptation

1. **Impact assessment as Hazard** $(\Delta P_{D,S}, \Delta NCP_{D,S})$

$$\Delta F_{D,S} \times \frac{1}{NCP_{D,S}} \quad \text{or} \quad \Delta\left(F_{D,S} \times \frac{1}{NCP_{D,S}}\right)$$

2. **Impact assessment as Disaster（without adaptation）**

$$\Delta R_{D,S} = \Delta\left(F_{D,S} \times \frac{1}{NCP_{D,S}}\right) \times \frac{1}{SCP_{D,S}}$$

3. **Impact assessment as Disaster (with adaptation** $\Delta SCP_{D,S}$**)**

$$\Delta R_{D,S} = \Delta\left(F_{D,S} \times \frac{1}{NCP_{D,S}} \times \frac{1}{SCP_{D,S}}\right)$$

By Nakakita (2008)

Conclusions

- For deep impact assessments by climate change on natural disaster (not on hazard), we need information on
  - Current and projected natural condition ("satellite, in-situ, operational, campaign obs.", "GCM output")
  - Current water management rules and underlying concepts
  - Current and historical social environment
  - Culture and religion for "accepting" and "adapting to" natural hazards (may be something are common in AP regions)

KAKUSHIN