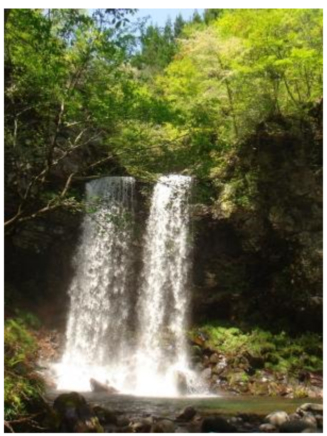
HydroECO2011
3rd International Multidisciplinary Conference on Hydrology and Ecology

Developing Integrated Hydrological Model for River Ecosystem Assessment




Nagara River

Yoshinobu SATO, Toshiharu KOJIRI
Yuri MICHIHIRO, Yasushi SUZUKI

Water Resources Research Center (WRRC)
Disaster Prevention Research Institute (DPRI)
Kyoto University, JAPAN

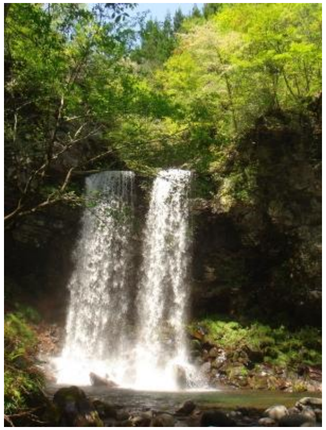
Uji River

Katsura River


Mogami River

Outline

Developing Integrated Hydrological Model for River Ecosystem Assessment



I. Introduction (background and objectives)

II. Methods -*Model structure*

III. Results and Discussion (Eco-hydrological impact assessment)

1. Climate change
2. Reservoir operation
3. Water temperature and Potential vegetations

IV. Conclusion

I. Introduction

Integrated Hydrological Model for River Ecosystem Assessment

Global warming…

Disappearance of permafrost layer

Glacial recession

Extreme events

Frequent Flood

Severe Drought

Disaster Prevention

Land use

Food production

Water use

Economic development
Population change

Reservoir operation

Selective water intake system

Water Resources Management

Fish pass system

River Environment & Ecosystem Conservation

II. Method -1/8

Distributed Hydrological Model

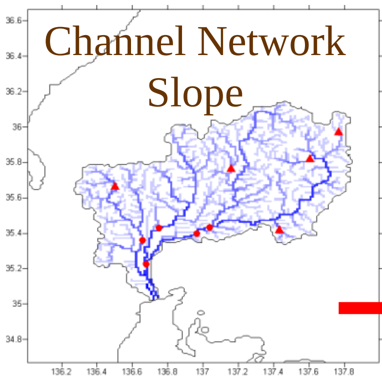
Spatial resolution: 1km

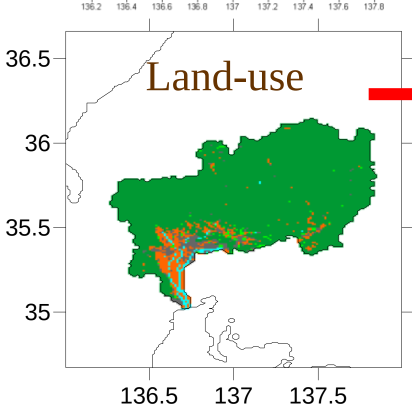
Output time step: 1h

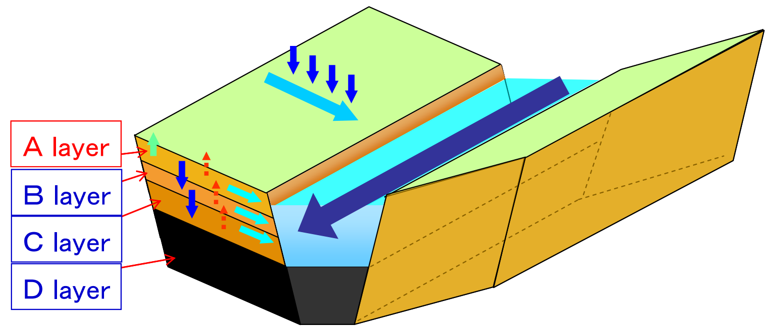
Physical Based Distributed Model

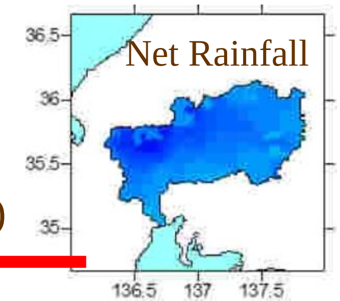
Hydro-BEAM

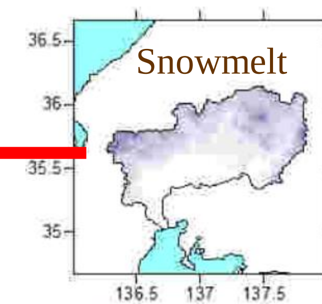
(**Hydro**logical river **B**asin **E**nvironment **A**ssessment **M**odel)

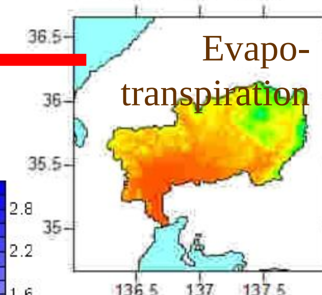




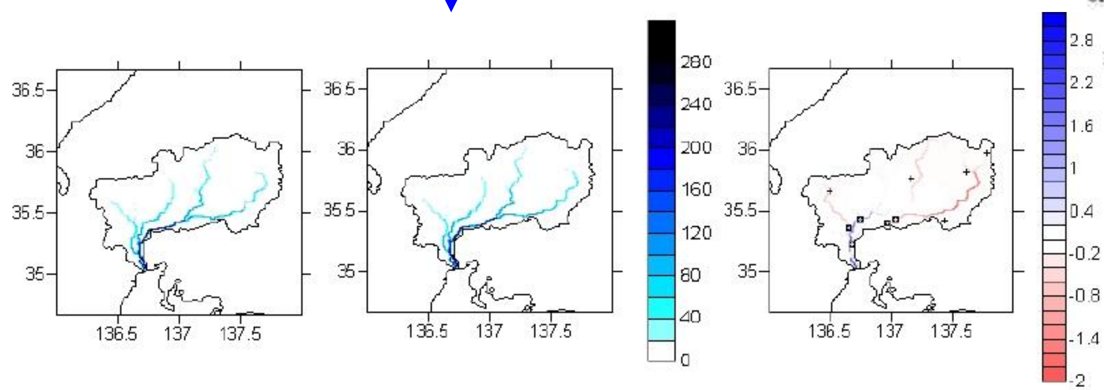








Runoff Analysis

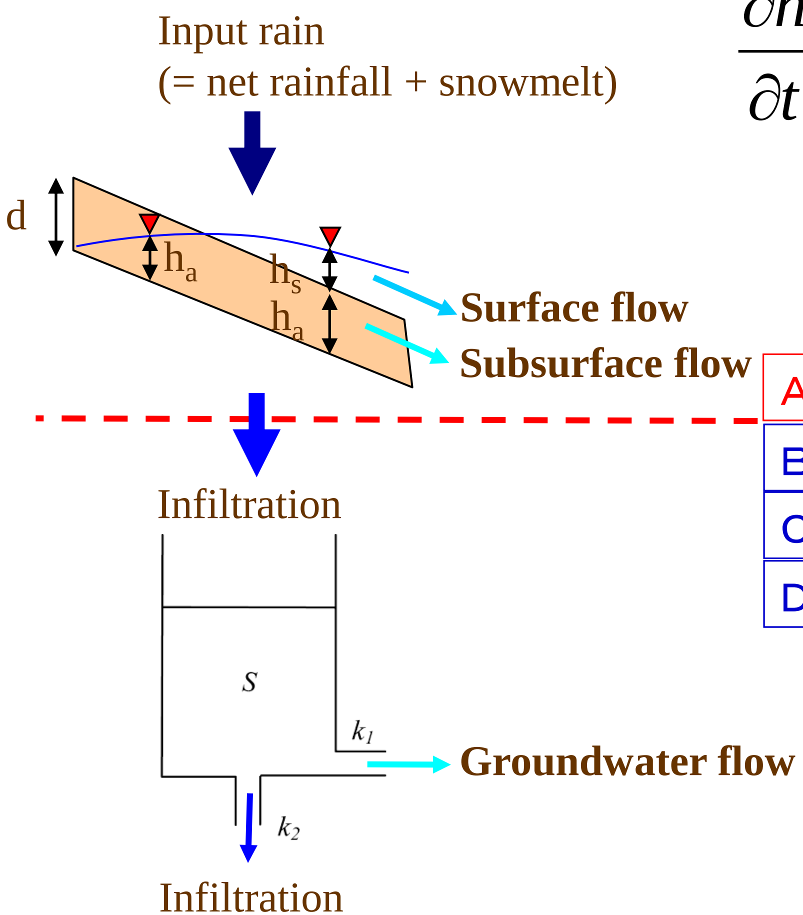


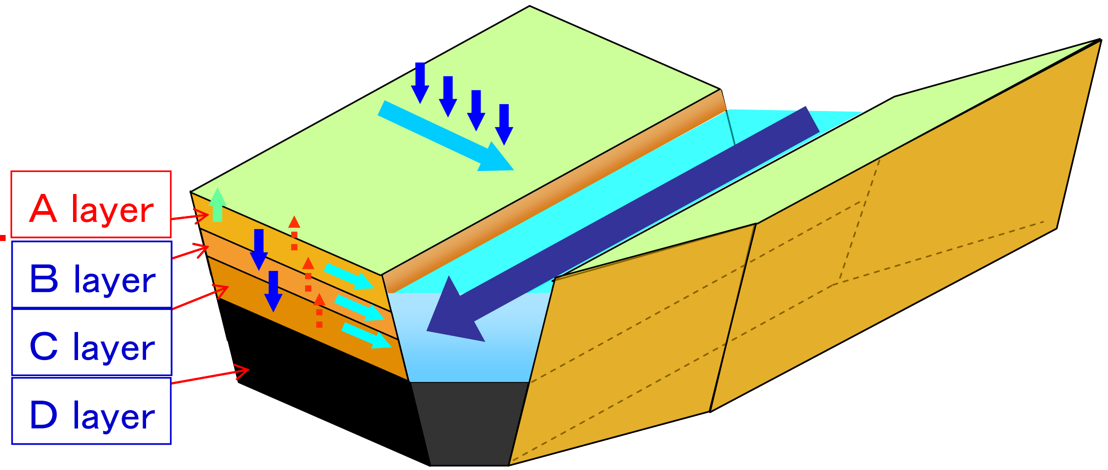
II. Method -2/8

Runoff process 1

Kinematic wave model

$$\frac{\partial h}{\partial t}+\frac{\partial q}{\partial x}=r \qquad \begin{cases} q=f(h)=\alpha(h-d)^m+ah \\ h=h_s+h_a \end{cases}$$





Multi-layer Storage function model

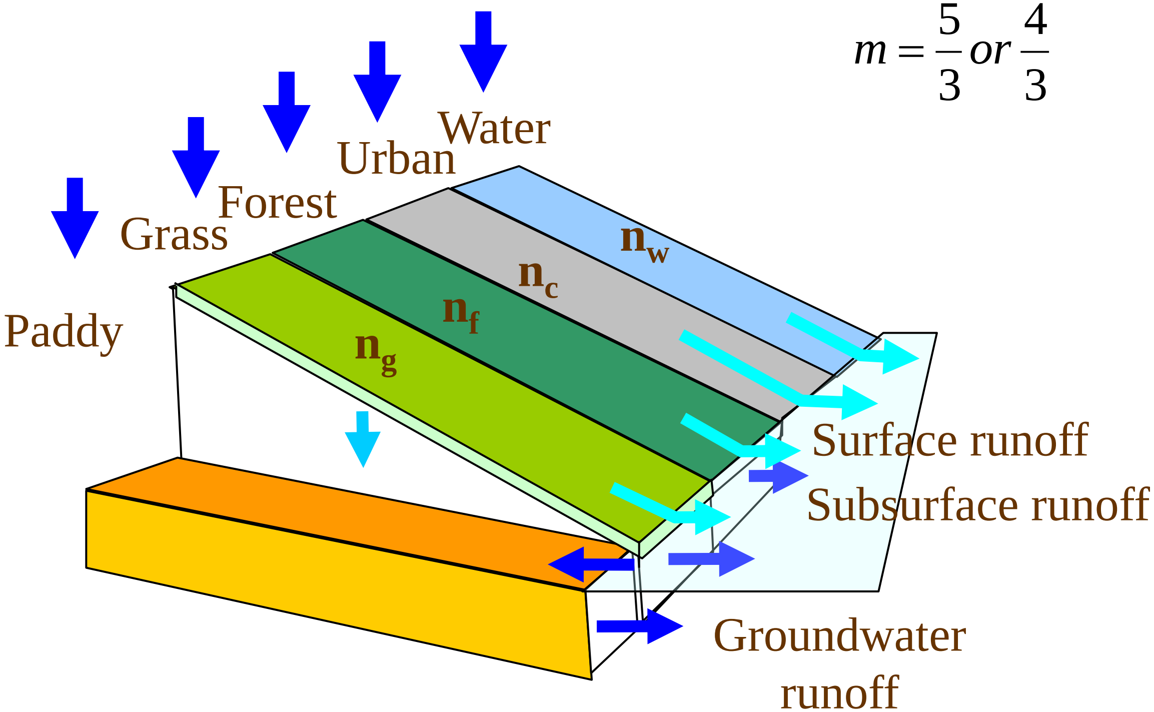
$$\frac{dS}{dt}=I-O \qquad O=(k_1+k_2)\cdot S$$

II. Method -3/8

Runoff process 2

Input rain

(net rainfall + snowmelt)



Surface runoff

$$q_s = \alpha h_s^{\,m} \quad \alpha = \frac{\sqrt{i}}{n}$$

$$m = \frac{5}{3} \, or \, \frac{4}{3}$$

Subsurface runoff

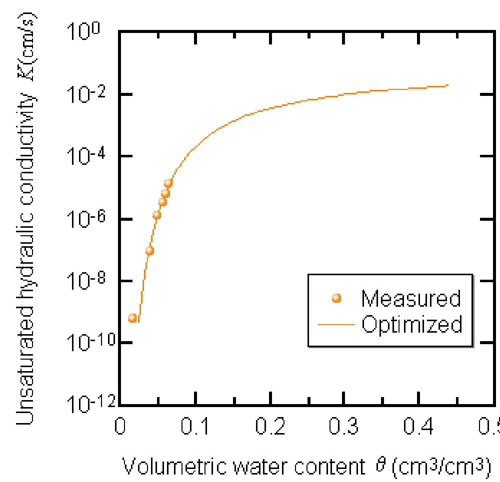
$$q_a = a h_a \quad a = K(\theta) i$$

i: slope gradient

n: surface roughness

K: hydraulic conductivity

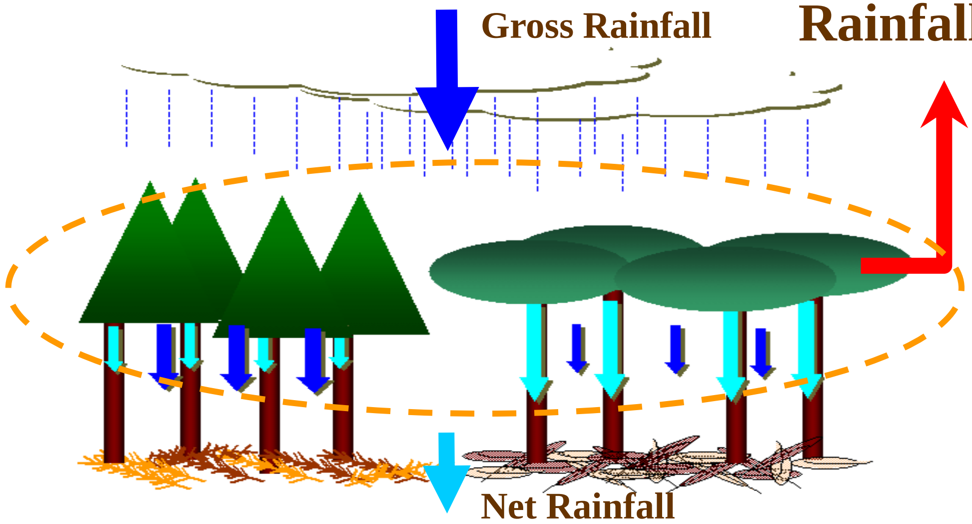
θ: volumetric water content

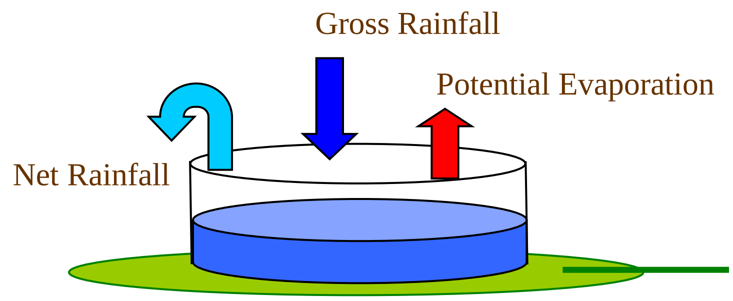


II. Method -4/8

Rainfall interception

Rainfall Interception

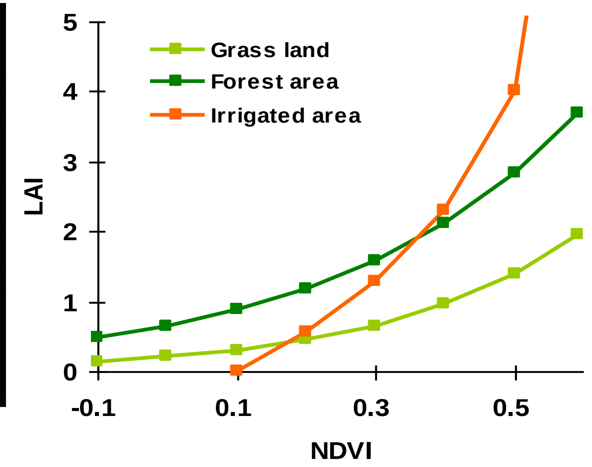




Interception storage capacity

Fish-eye's view canopy image

LAI: Leaf Area Index



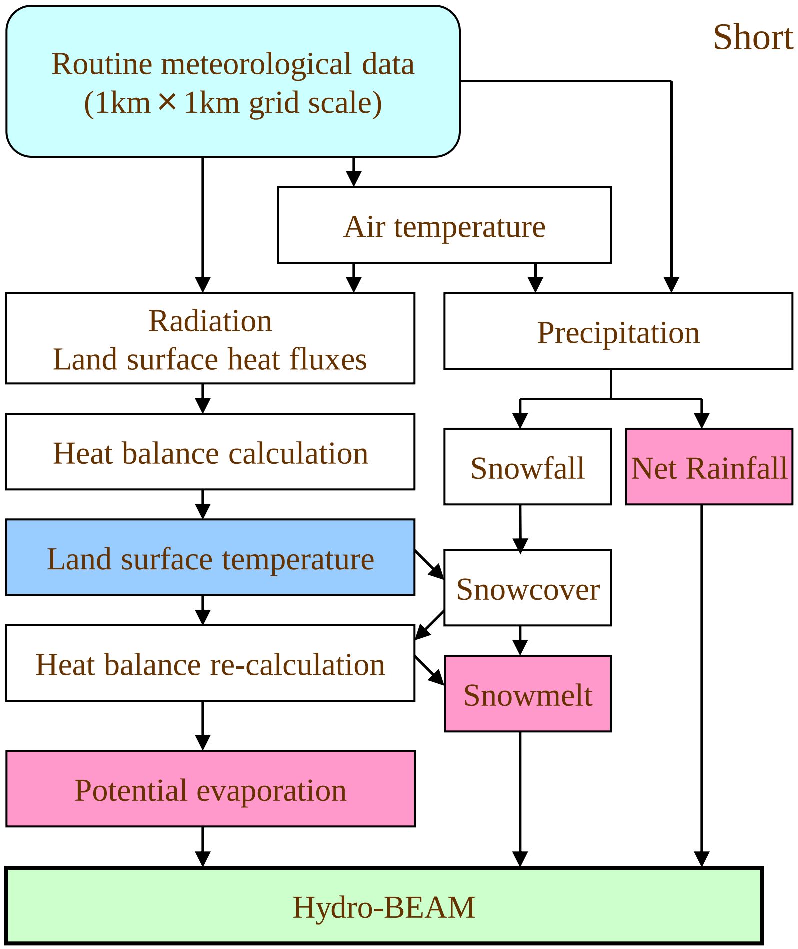
Normalized Difference Vegetation Index
(Remote Sensing Satellite Data)

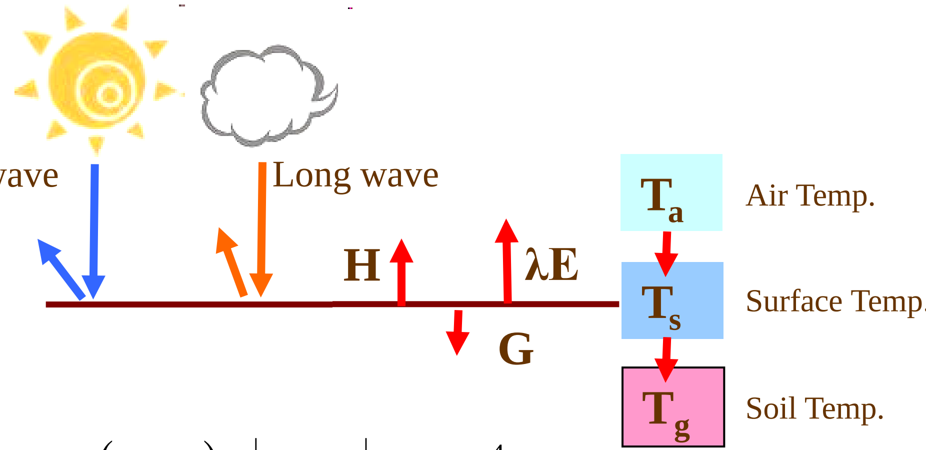
II. Method -5/8

Land surface and soil heat balance

Heat balance model

Sato et al (2008) Hydrological Processes 22



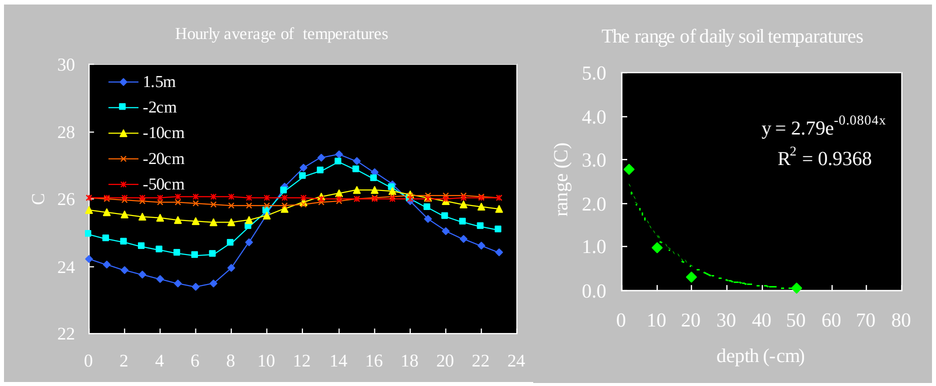


$$(1-\alpha)S^{\downarrow} + \varepsilon L^{\downarrow} = \sigma T^4 + H + \lambda E + G$$

$$H = c_p \rho C_H U (Ts - Ta)$$

$$L = \lambda \rho \beta C_H U (q_{sat}(Ts) - qa)$$

Vertical profiles of soil temperature



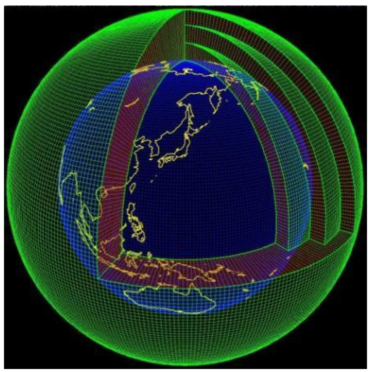
Surface/Soil temperature → Water temperature

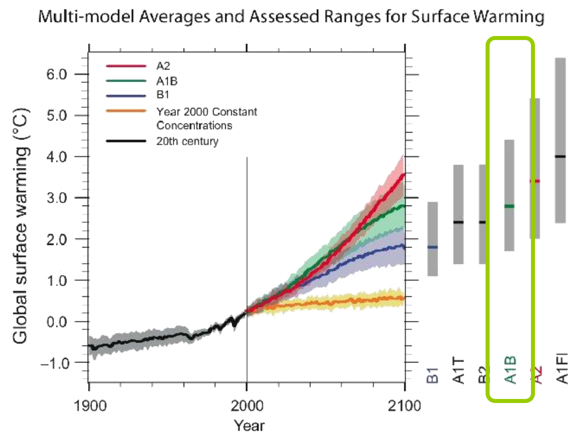
II. Method -6/8
Input data

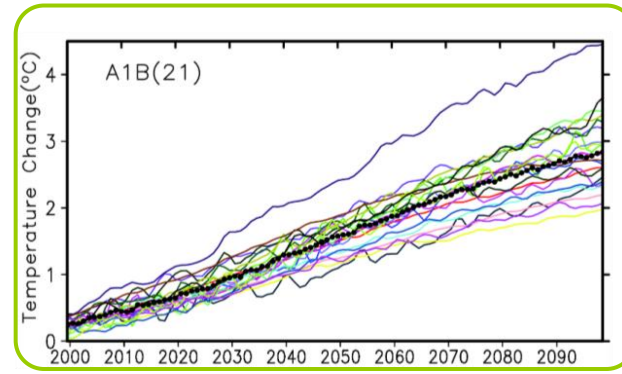
GCMs（General Circulation Models）

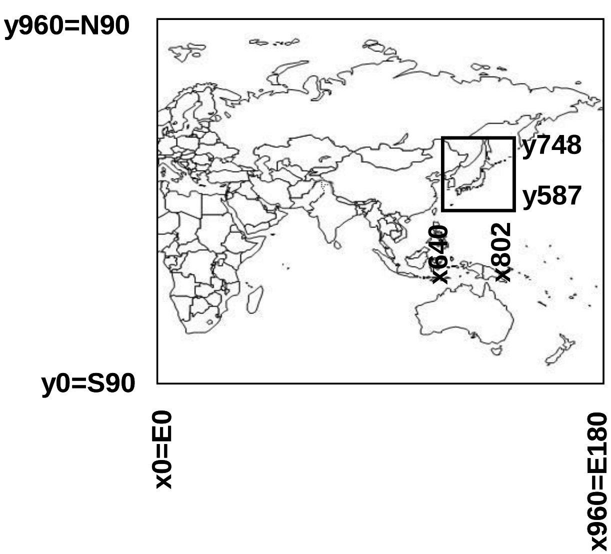
CMIP3 (Coupled Model Intercomparison Project phase3)

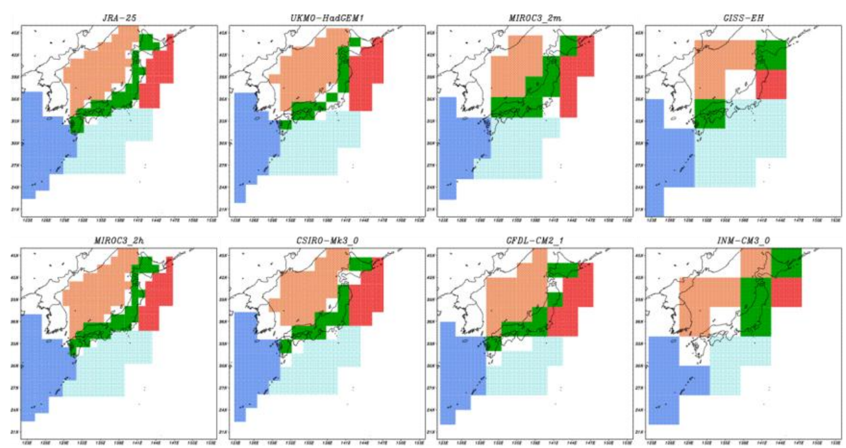
PCMDI (Program for Climate Model Diagnosis and Intercomparison)







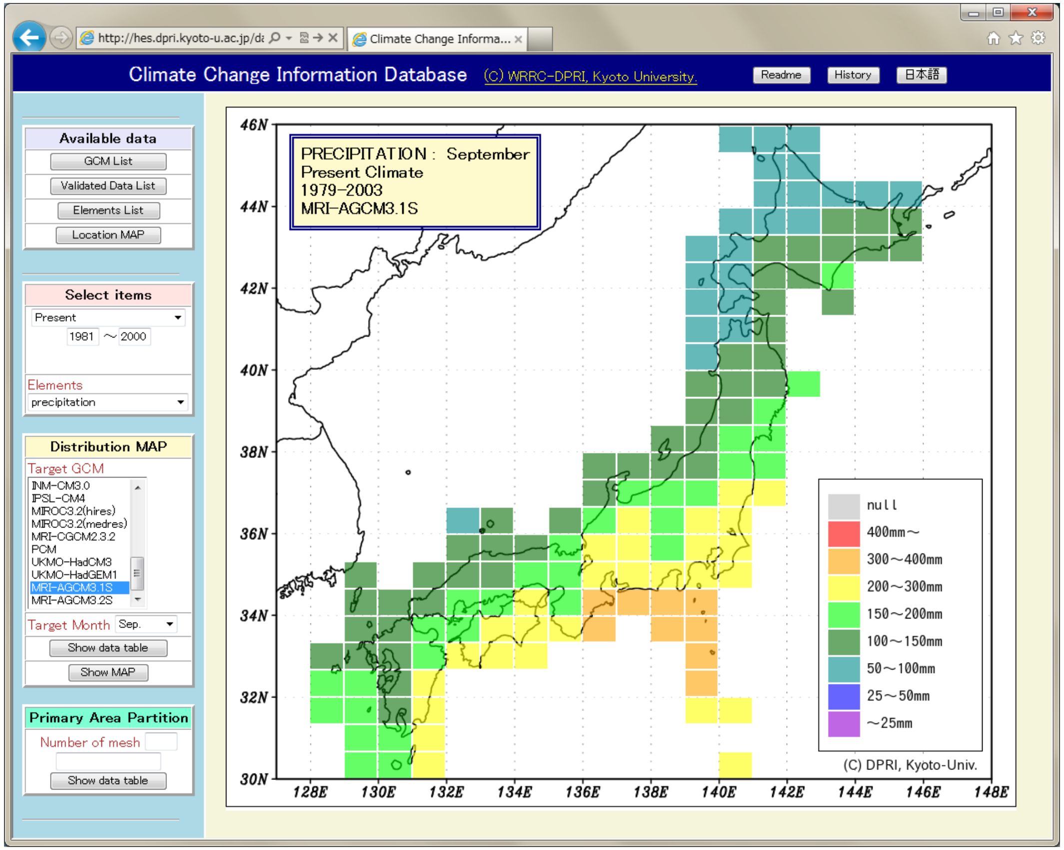


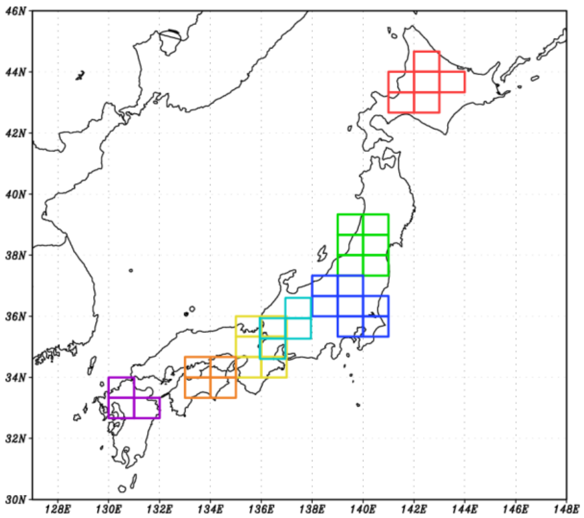


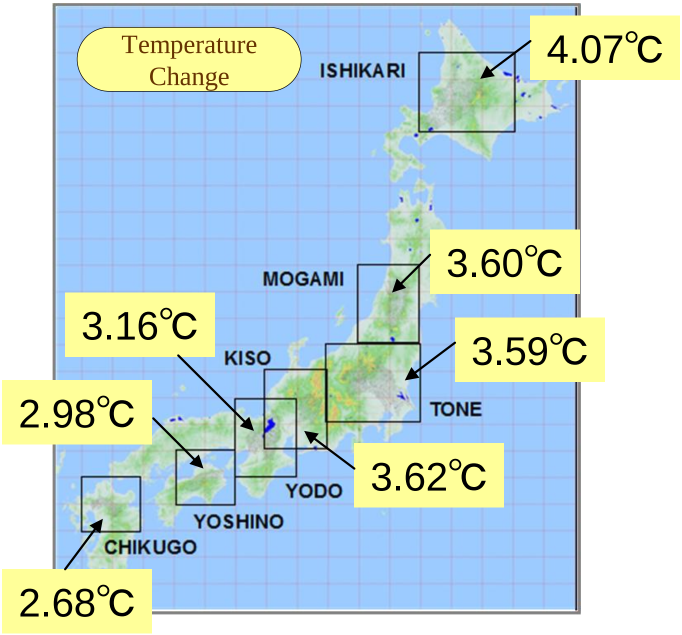
II. Method -7/8
Analytical procedure

Climate Change Information Database

A2 | A1B | B1





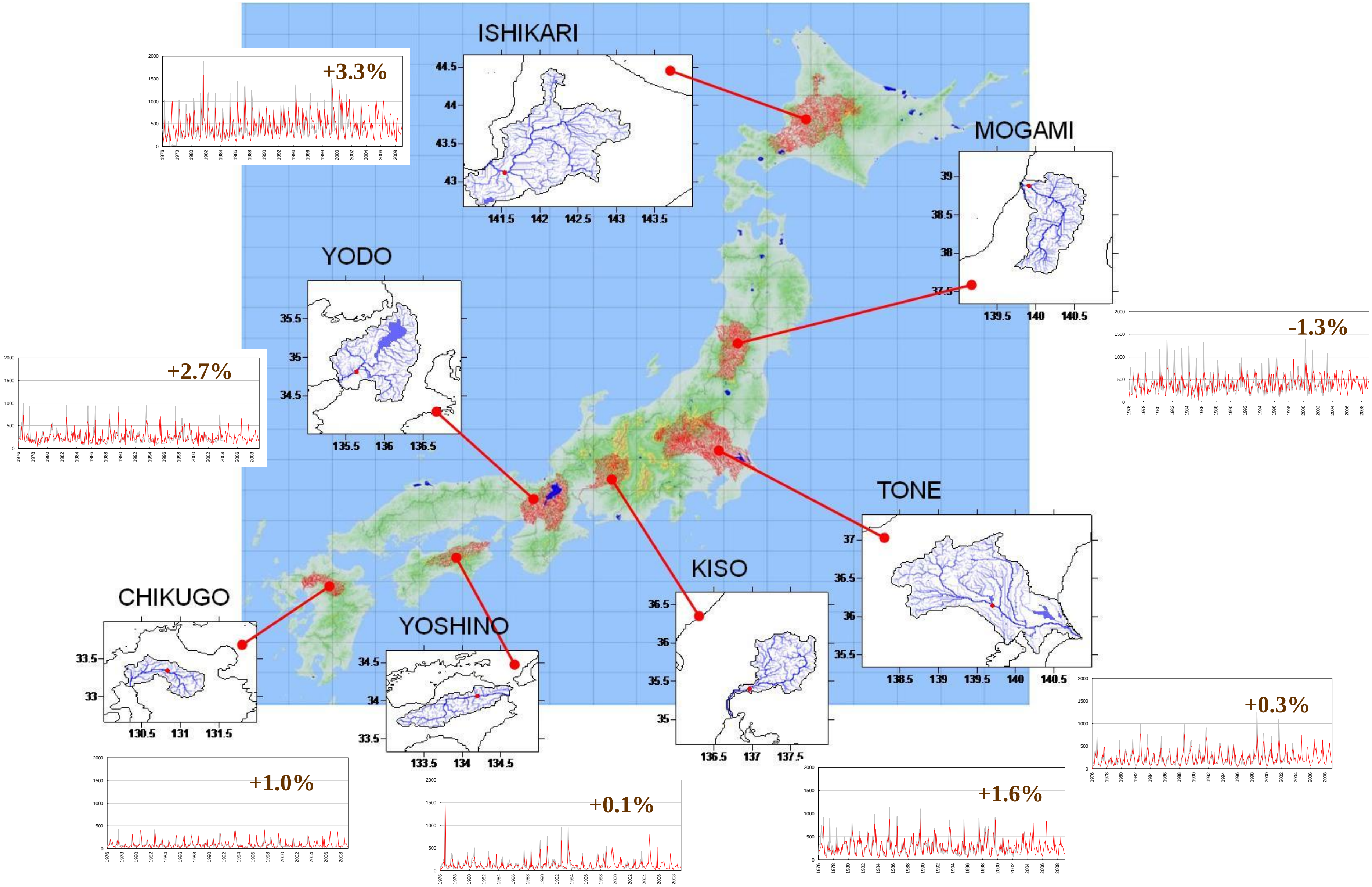


Multi-Scenario analysis
Multi-Model analysis

http://hes.dpri.kyoto-u.ac.jp/database/

II. Method -8/8

Study areas and model performance

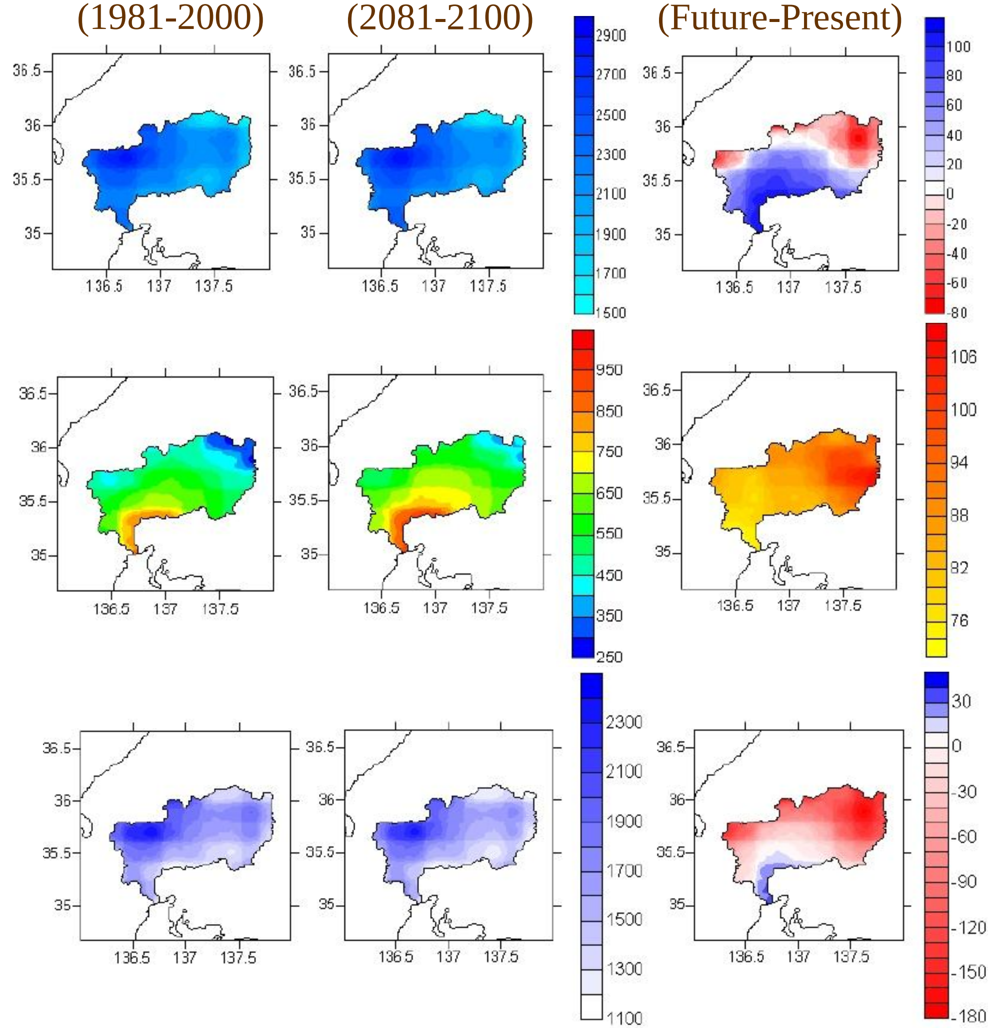


III. Results and Discussion -1/5

Impact of Climate Change (A1B scenario)

Kiso (three) river basin

	Present (1981-2000)	**Future** (2081-2100)	**Change** (Future-Present)
Precipitation			
Evapotranspiration			
Available Water resources = Prec. – Evapt.			



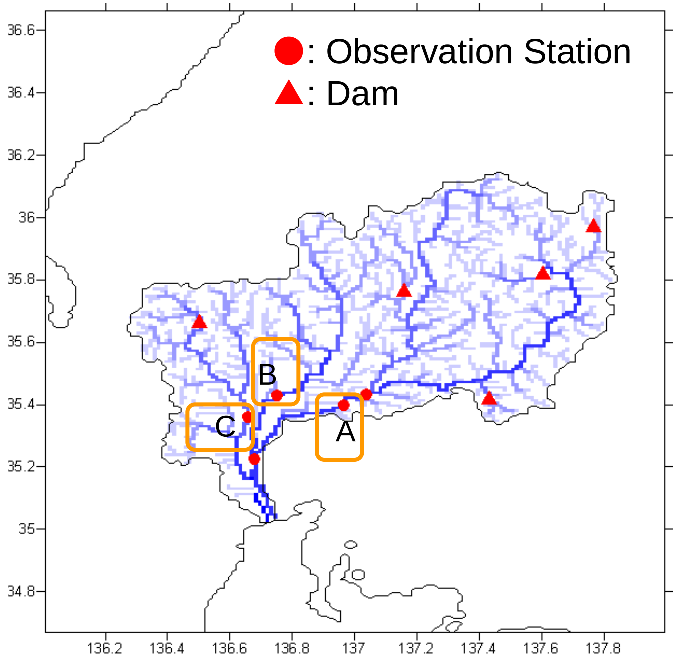
Distributed hydrological model can detect the impact of climate change more precisely.

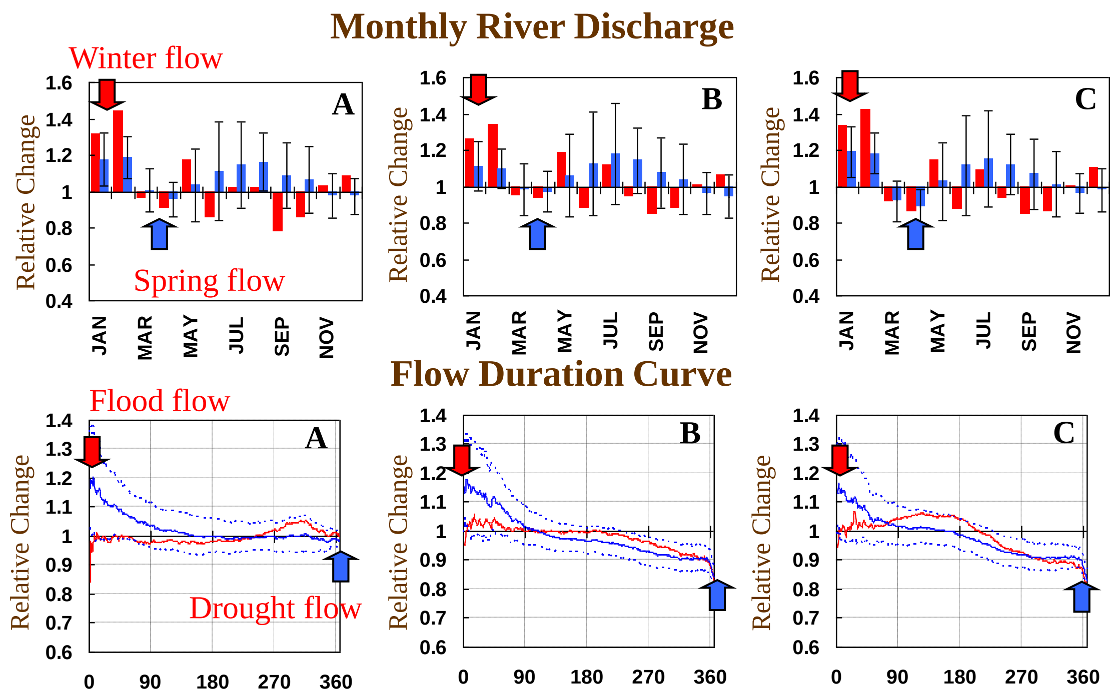
III. Results and Discussion -2/5

Runoff Analysis(A1B scenario)

—CMIP3 —AGCM20

※Error bars indicate the range between Max and Min.



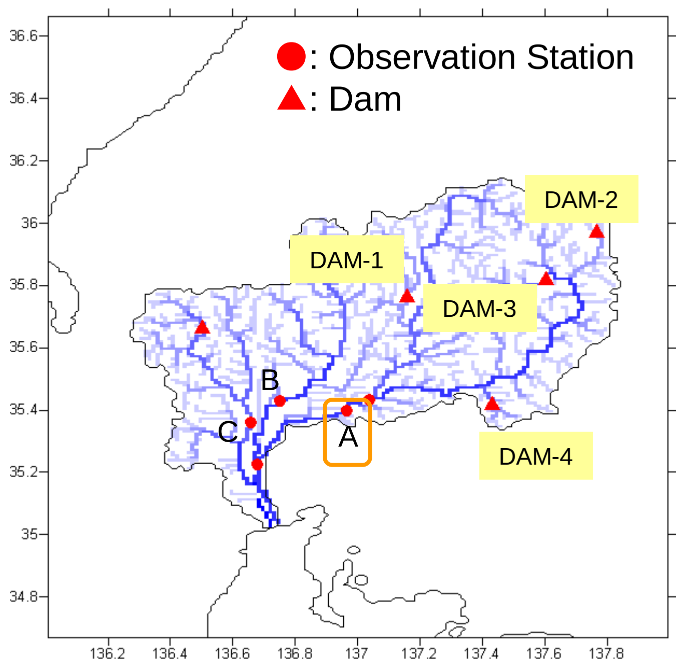


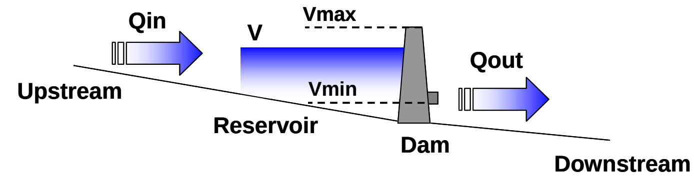
Winter flow will increase about 20~40%
Spring flow will decrease about 10%
Flood flow will increase about 20%
Drought flow will decrease about 10~20% (Station B and C).

More sever flood and drought will occur under the future climate condition.

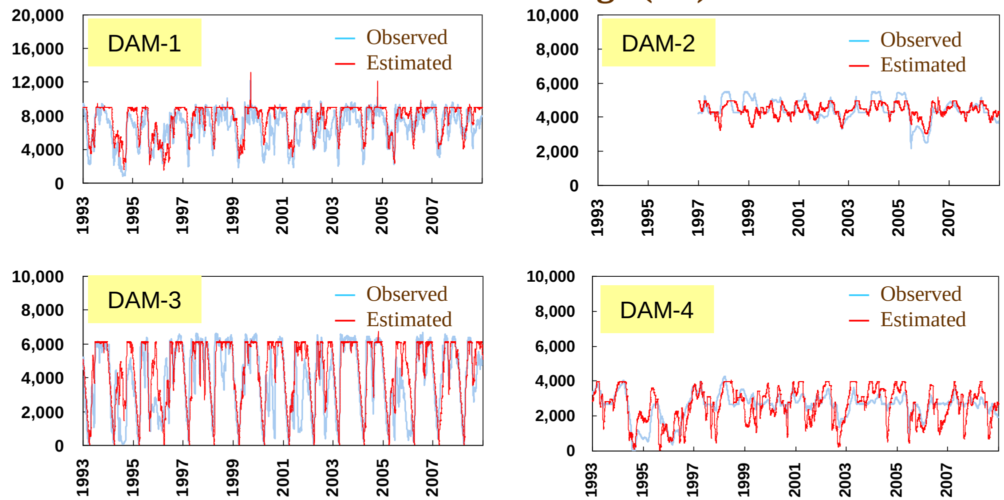
III. Results and Discussion -3/5

Reservoir operation

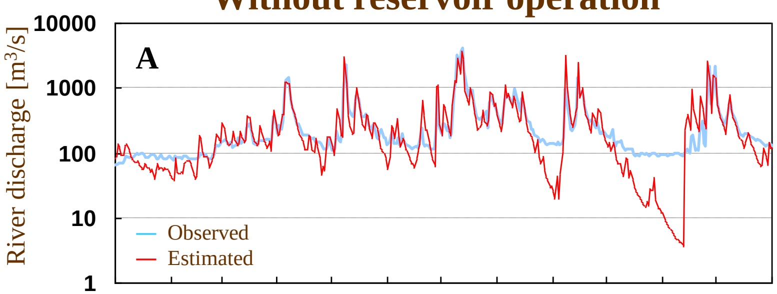




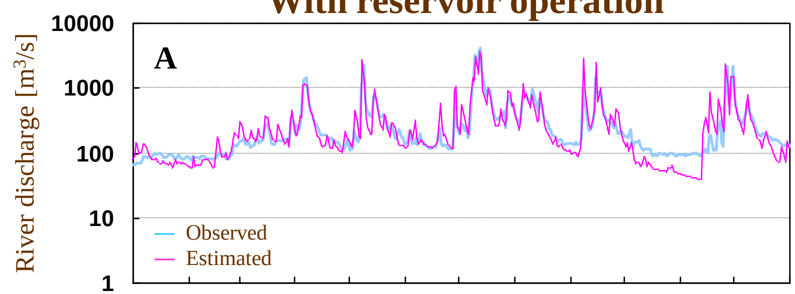
Reservoir water storage (m^3)



Without reservoir operation



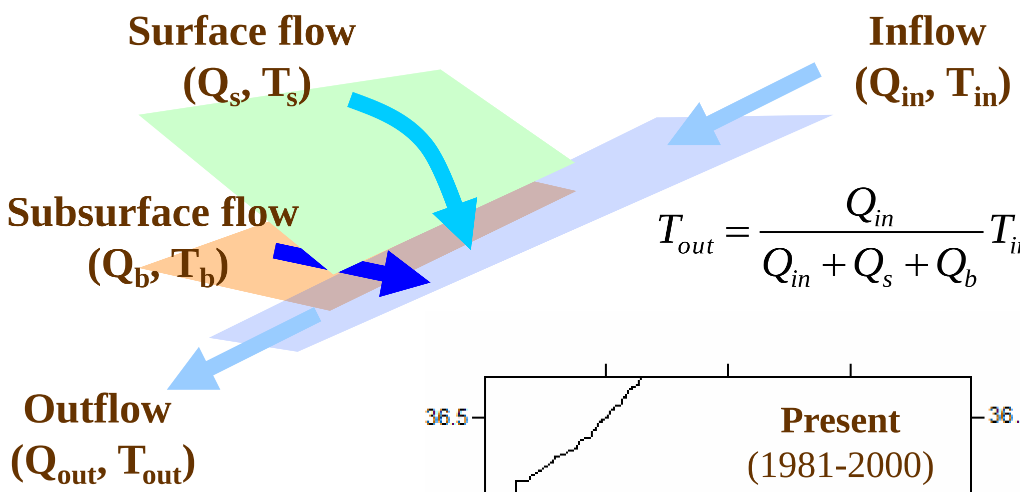
With reservoir operation



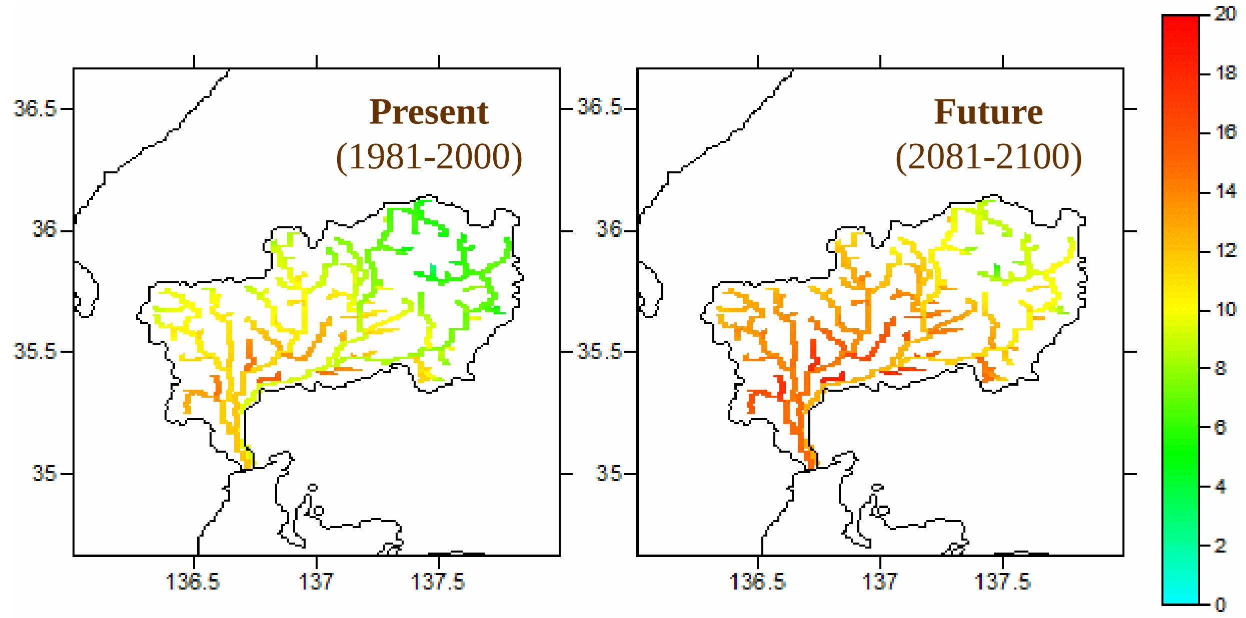
The reservoir operation will contribute to keep the river flow in the water shortage period.

III. Results and Discussion -4/5

Water temperature



$$T_{out} = \frac{Q_{in}}{Q_{in}+Q_s+Q_b}T_{in} + \frac{Q_s}{Q_{in}+Q_s+Q_b}T_s + \frac{Q_b}{Q_{in}+Q_s+Q_b}T_b$$



The information of spatial distribution of water temperature will contribute to river ecosystem or environment assessment.

III. Results and Discussion -5/5

Potential vegetation

Warmth Index (WI)

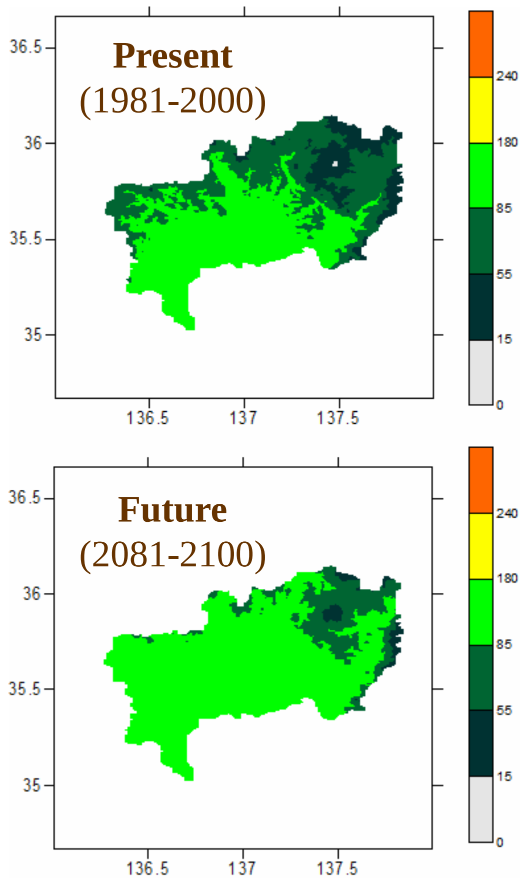
Monthly Air Temperature (T_m)

$$WI = \sum_{m=1}^{12} (T_m - 5) \cdots if\ (T_m \geq 5)$$

Wet and Dry Index (WDI)

Annual precipitation (P_g) & WI

$$WDI = \left[\begin{array}{l} \dfrac{P_g}{WI + 20} \ldots if\ (WI < 100) \\ \dfrac{2P_g}{WI + 140} \cdots if\ (WI \geq 100) \end{array} \right]$$



Present (1981-2000)

- Tropical rain forest (0%)
- Subtropical rain forest (0%)
- Evergreen broadleaf forest (51%)
- Deciduous broad leaf forest (37%)
- Evergreen coniferous forest (12%)
- Tundra area (0.1%)

Future (2081-2100)

- Tropical rain forest (0%)
- Subtropical rain forest (0%)
- Evergreen broadleaf forest (81%)
- Deciduous broad leaf forest (17%)
- Evergreen coniferous forest (2%)
- Tundra area (0%)

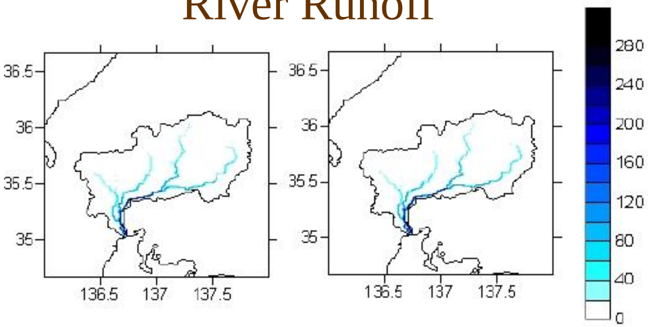
Land cover (Vegetation) type will change the long-term water balance and water quality in the future.

IV. Conclusion

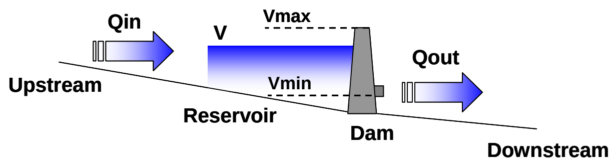
Developing Integrated Hydrological Model for River Ecosystem Assessment

The integrated hydrological model: **Hydro-BEAM**
(**<u>Hydro</u>**logical river **<u>B</u>**asin **<u>E</u>**nvironment **<u>A</u>**ssessment **<u>M</u>**odel) is developed (upgraded).
The model can be used for…

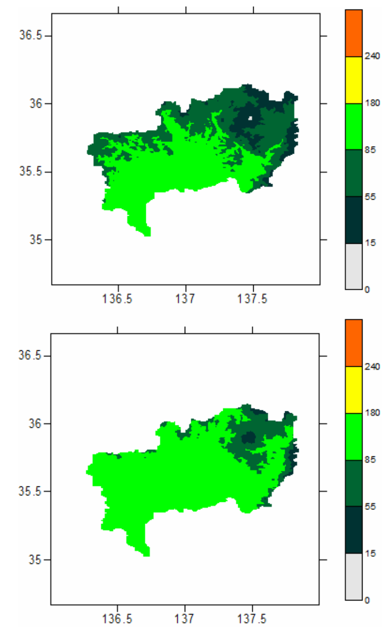
River Runoff



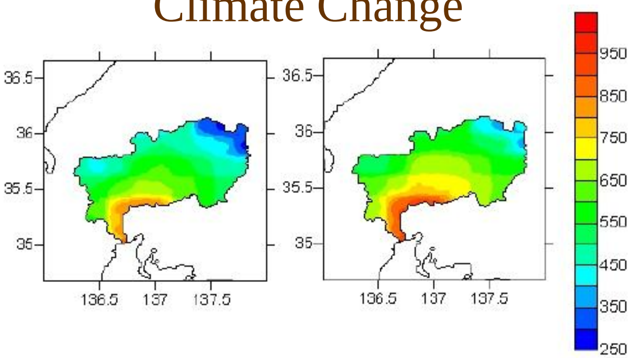
Reservoir operation Assessment



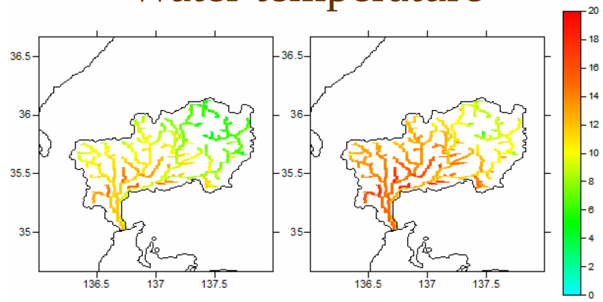
Vegetation Change



Climate Change

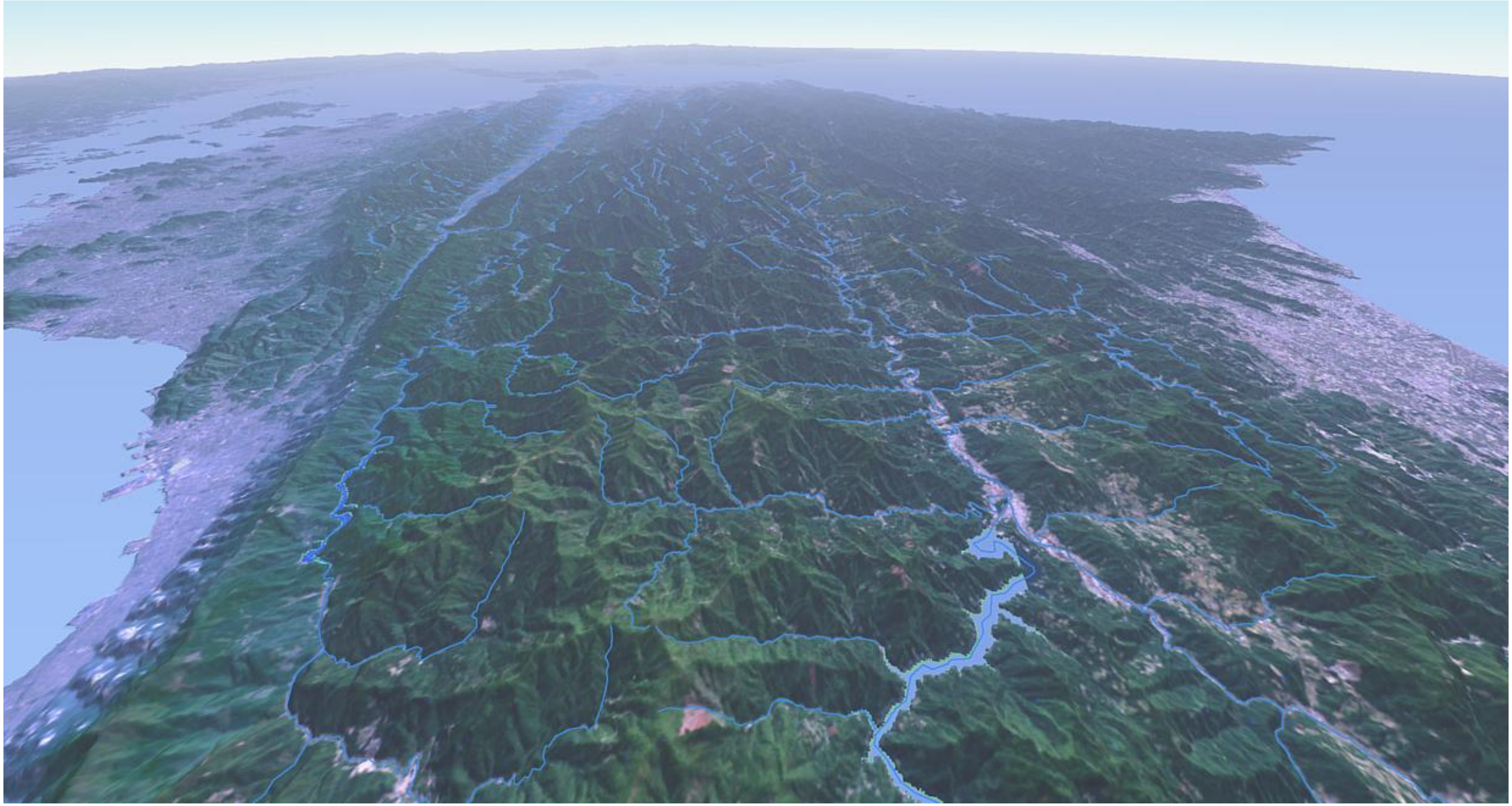


Water temperature



The model developed in this study will contribute to river ecosystem and environment assessment under the future climate conditions.

Thank you for your attention !



Bird's view composite with Landsat image of Yoshino River basin.