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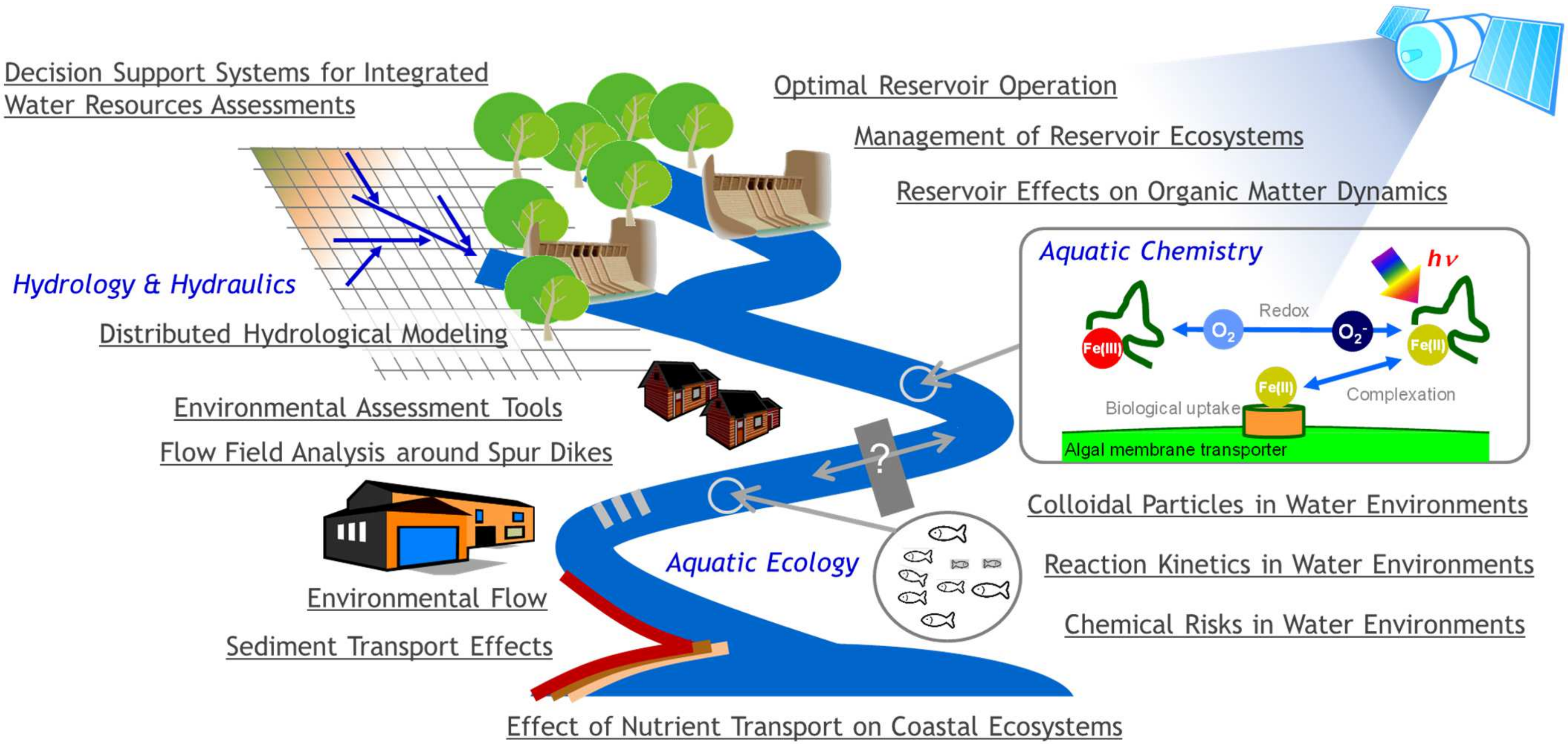
Extracting river flow characteristics for estimation of floods, sediment, fish population

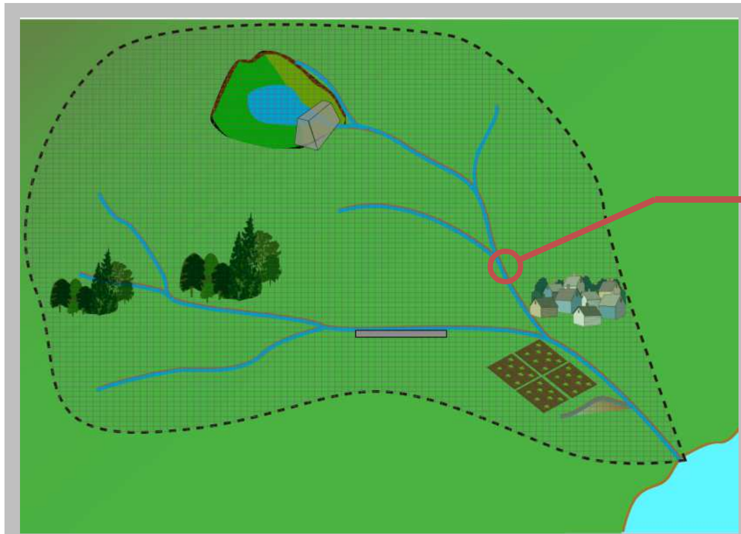
Oliver C. SAAVEDRA VALERIANO

Department of Civil Engineering and Environmental
Tokyo Institute of Technology, Japan

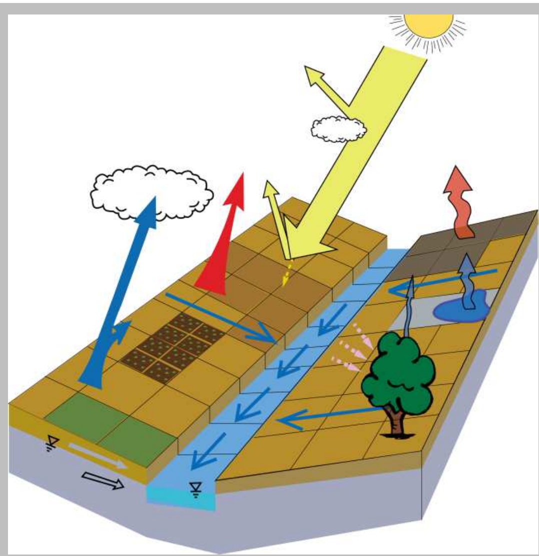
Overview of Water Environment



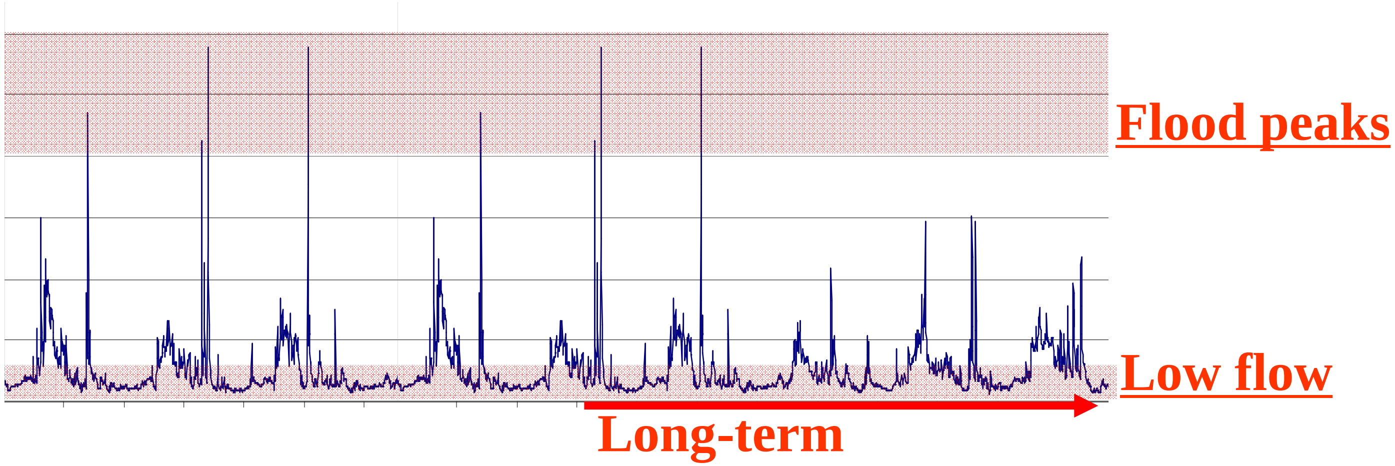
Regional & basin interaction

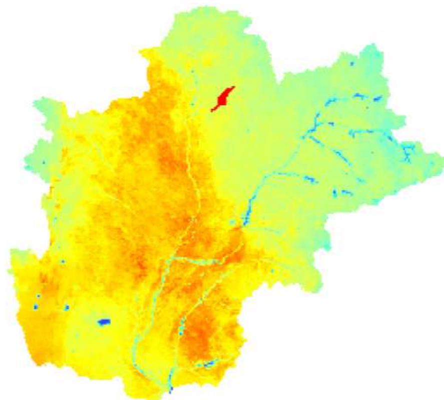


Regional hydrological & land surface models

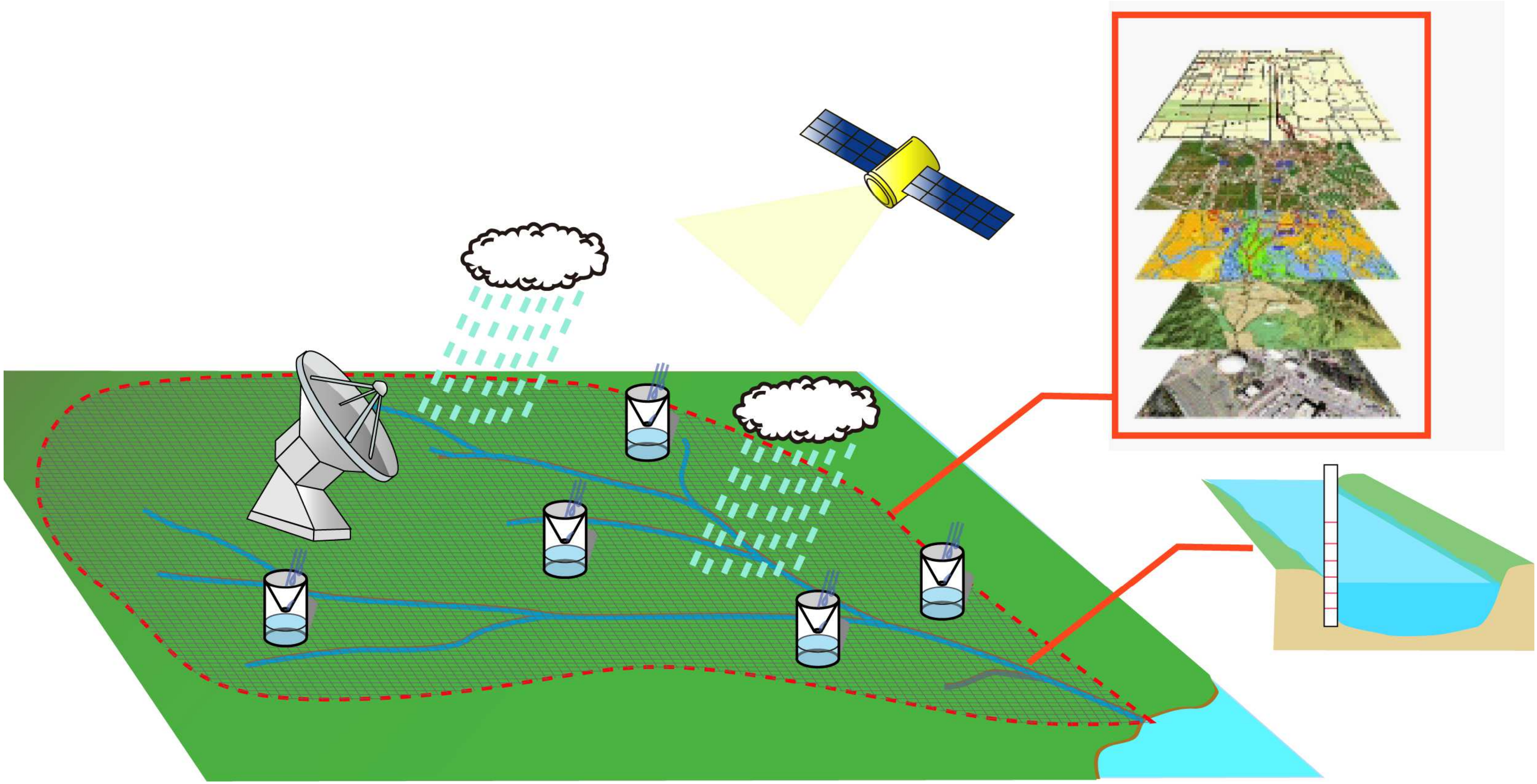


Distributed water & energy budget model

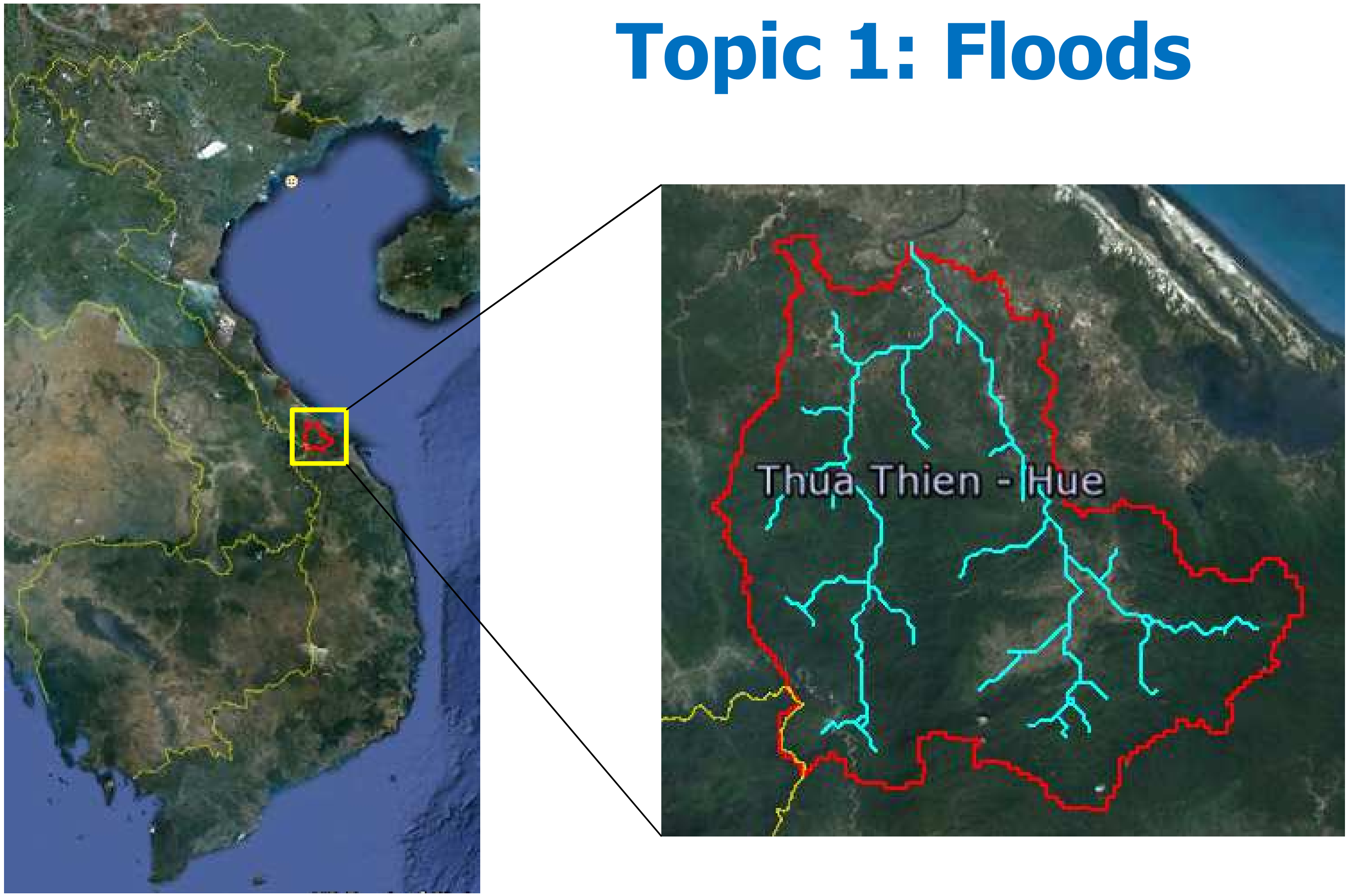




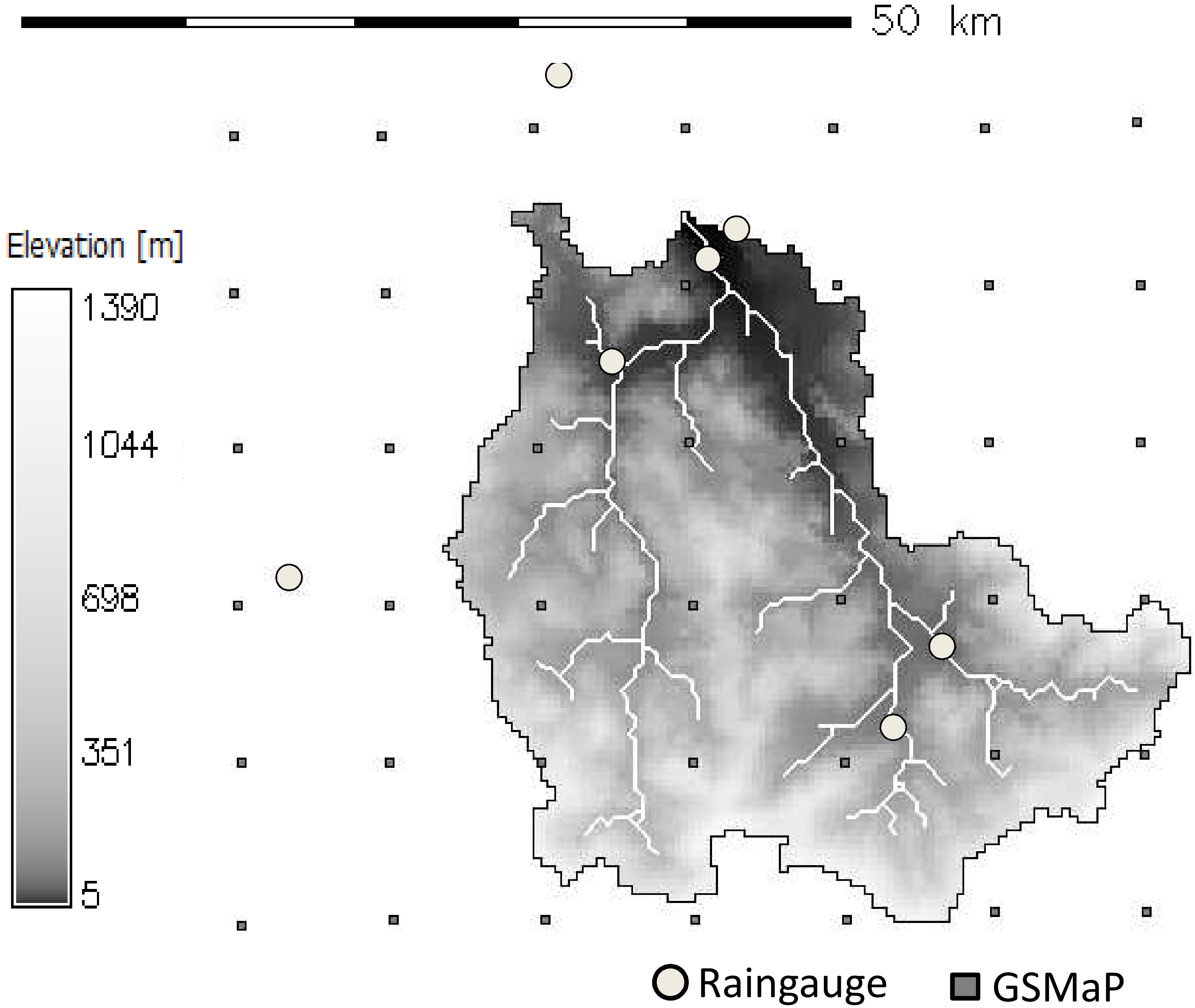
Input data to the model



Topic 1: Floods

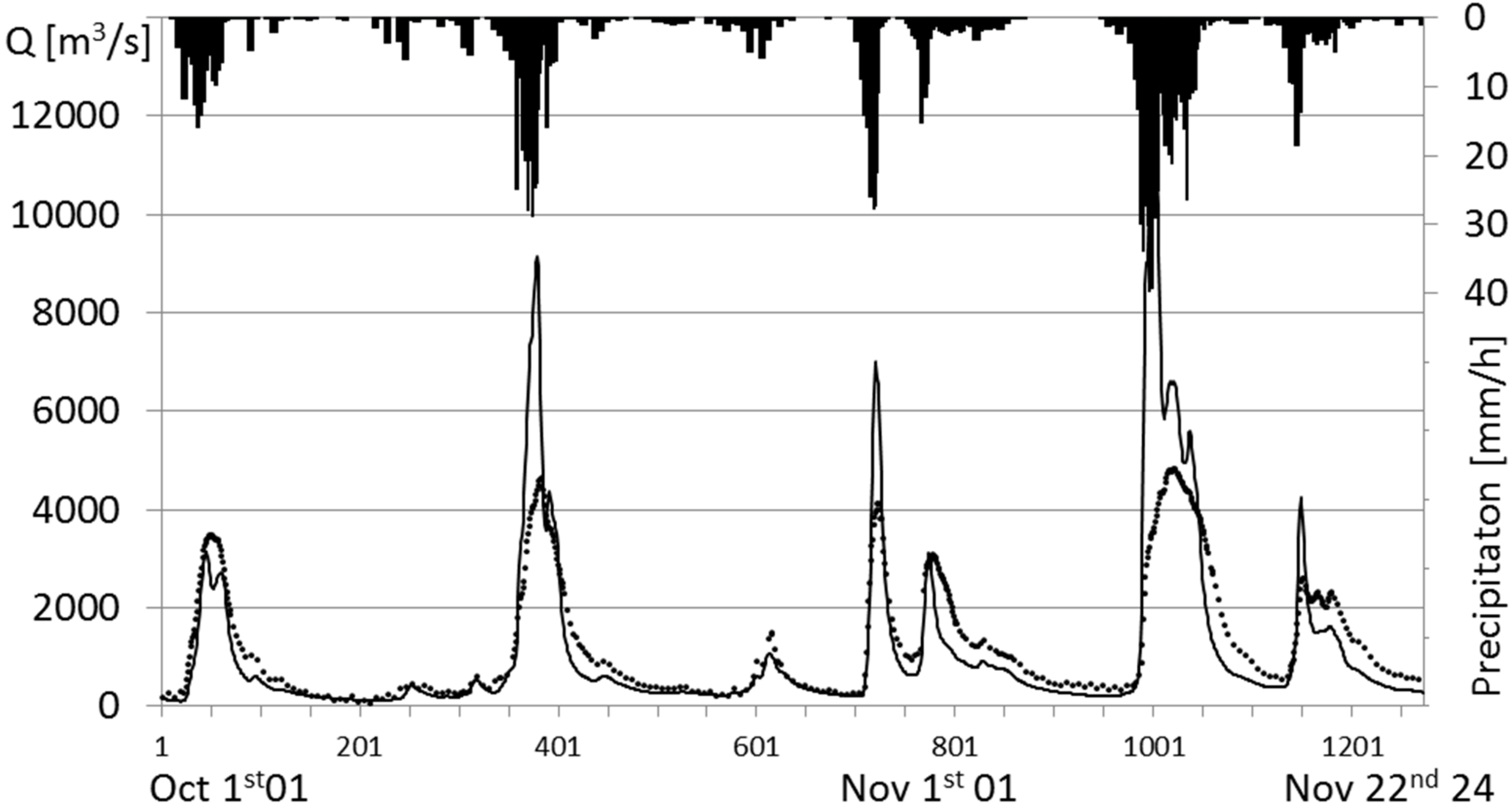


Oliver SAAVEDRA, Ryo MASAHIRO,
Toshio KOIKE, Tinh D. Ngoc

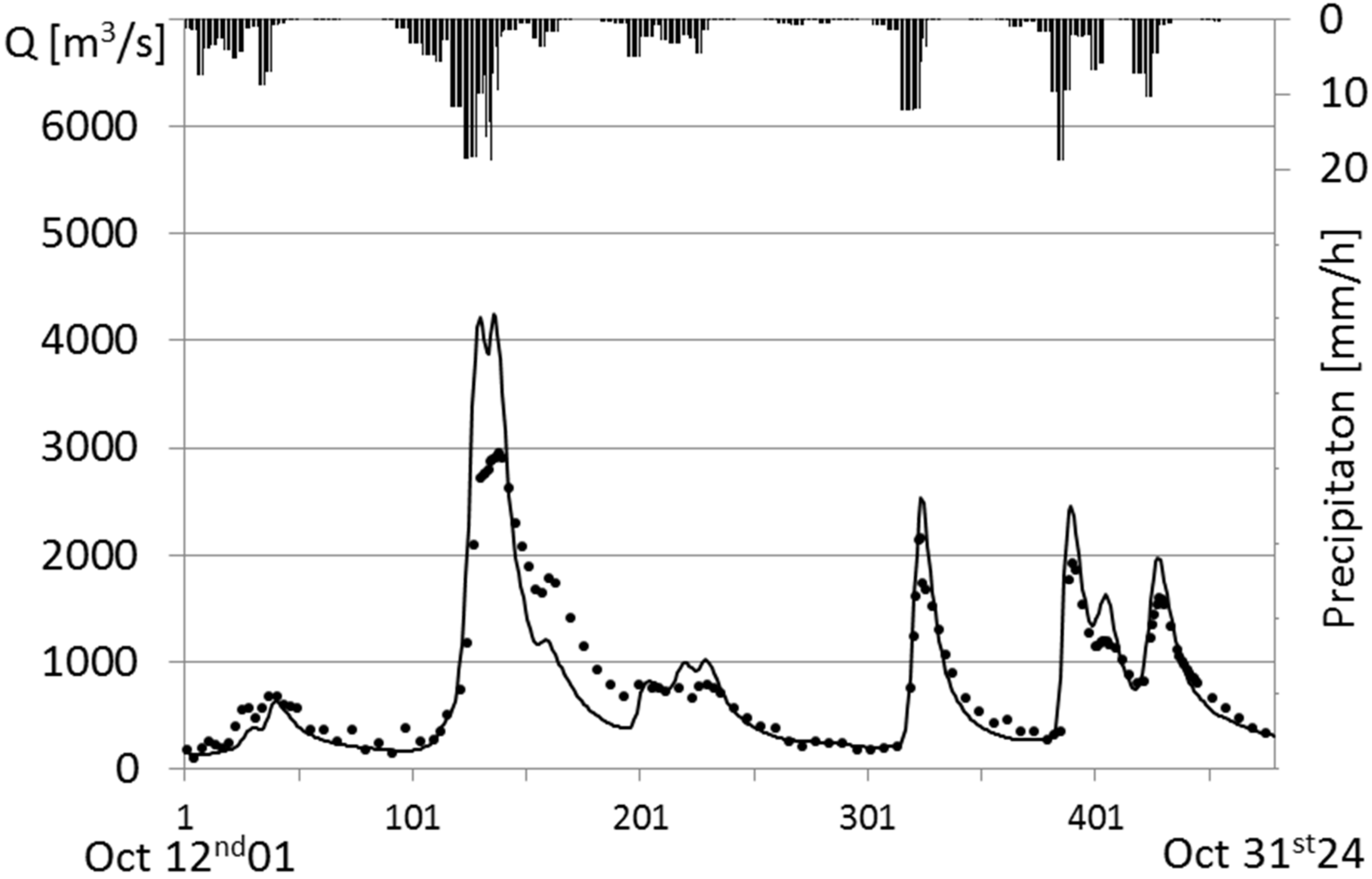


50 km
Elevation [m]
1390
1044
698
351
5
Raingauge
GSMaP

2007 Oct 1st to Nov 22nd



2008 Oct 1st to Oct 31st



2007 Oct 2nd 2:00 – 4:00

R-square

RG – GSMaP; R^2 = 0.40

RG – Mixed; R^2 = 0.76

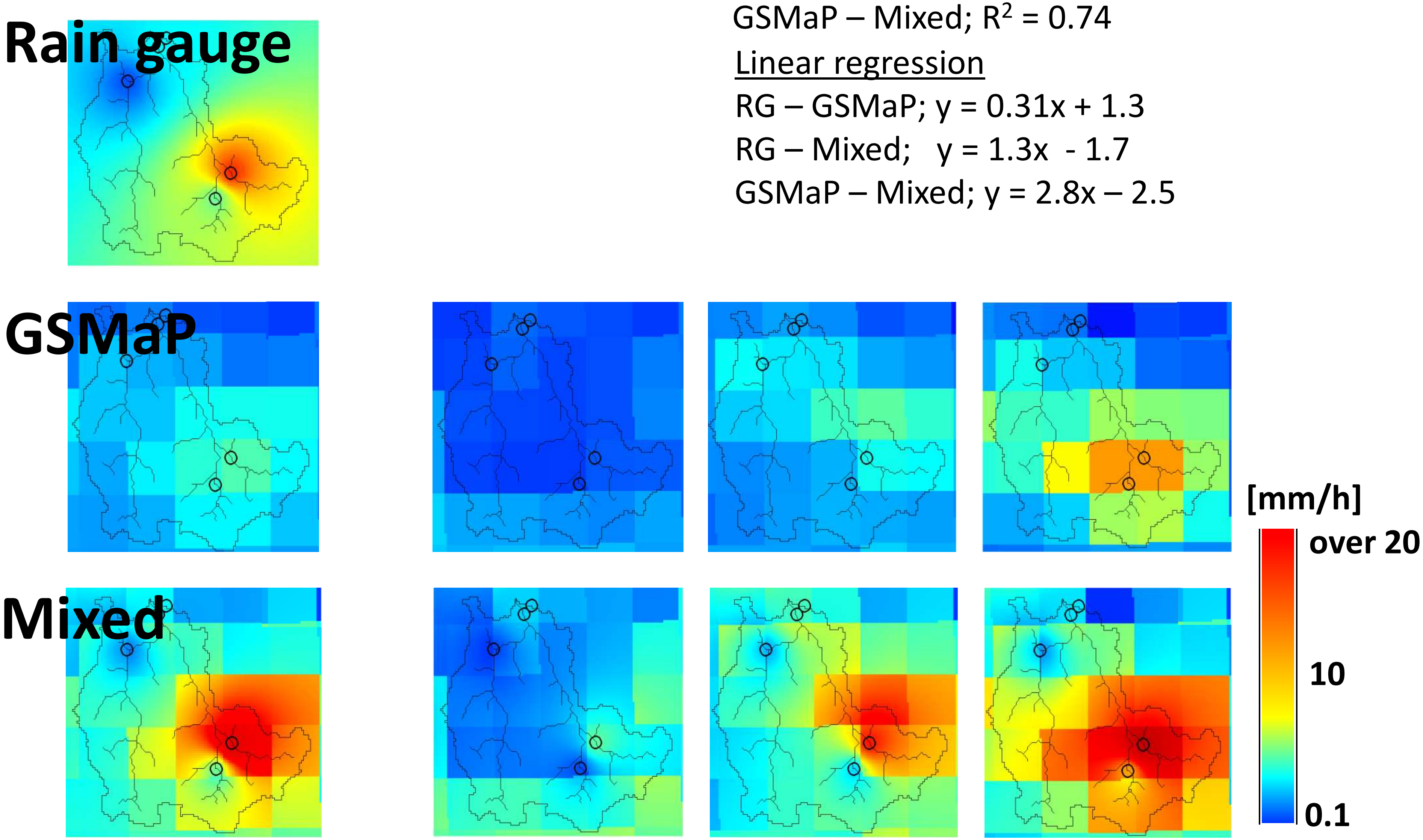
GSMaP – Mixed; R^2 = 0.74

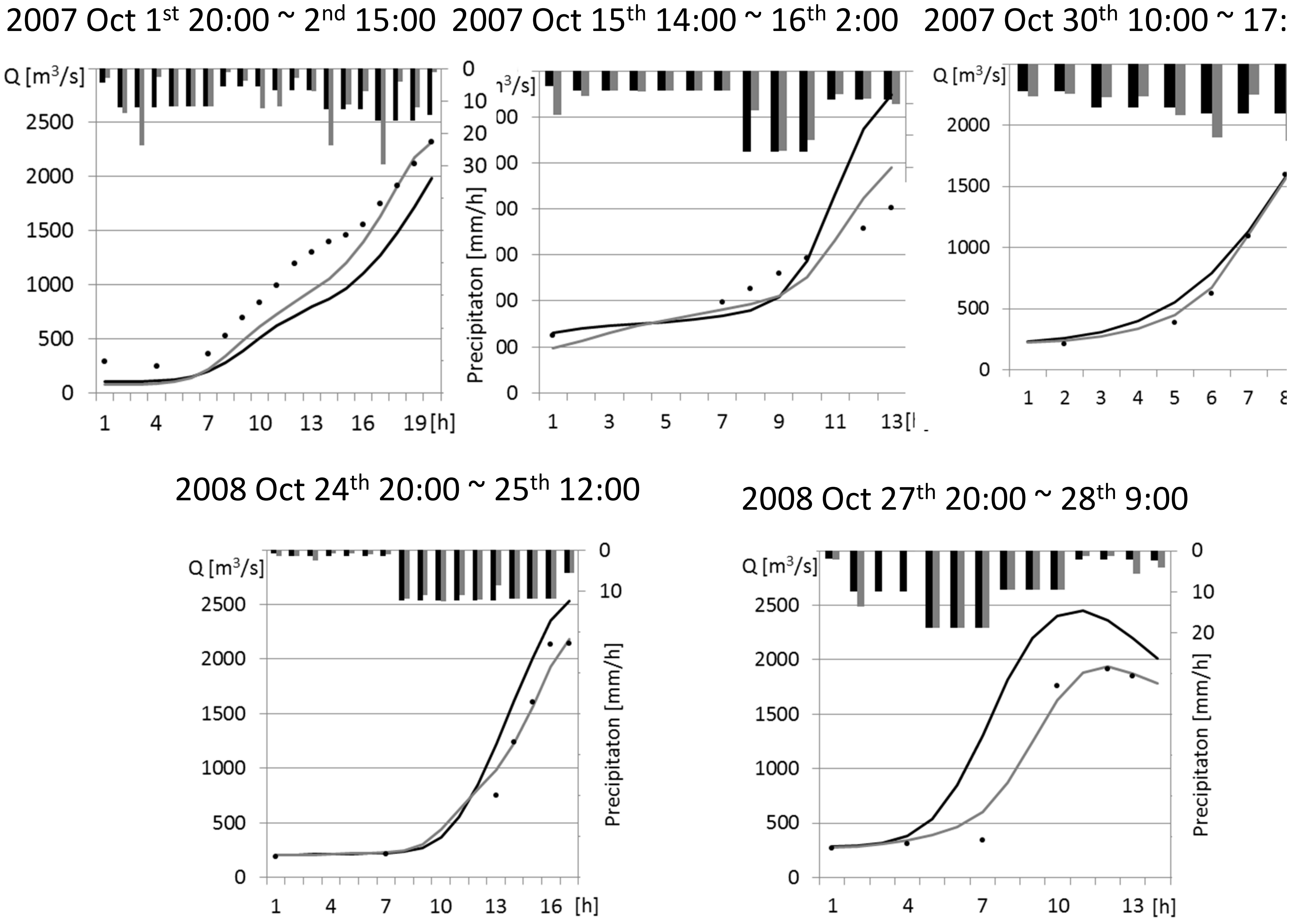
Linear regression

RG – GSMaP; y = 0.31x + 1.3

RG – Mixed; y = 1.3x - 1.7

GSMaP – Mixed; y = 2.8x – 2.5

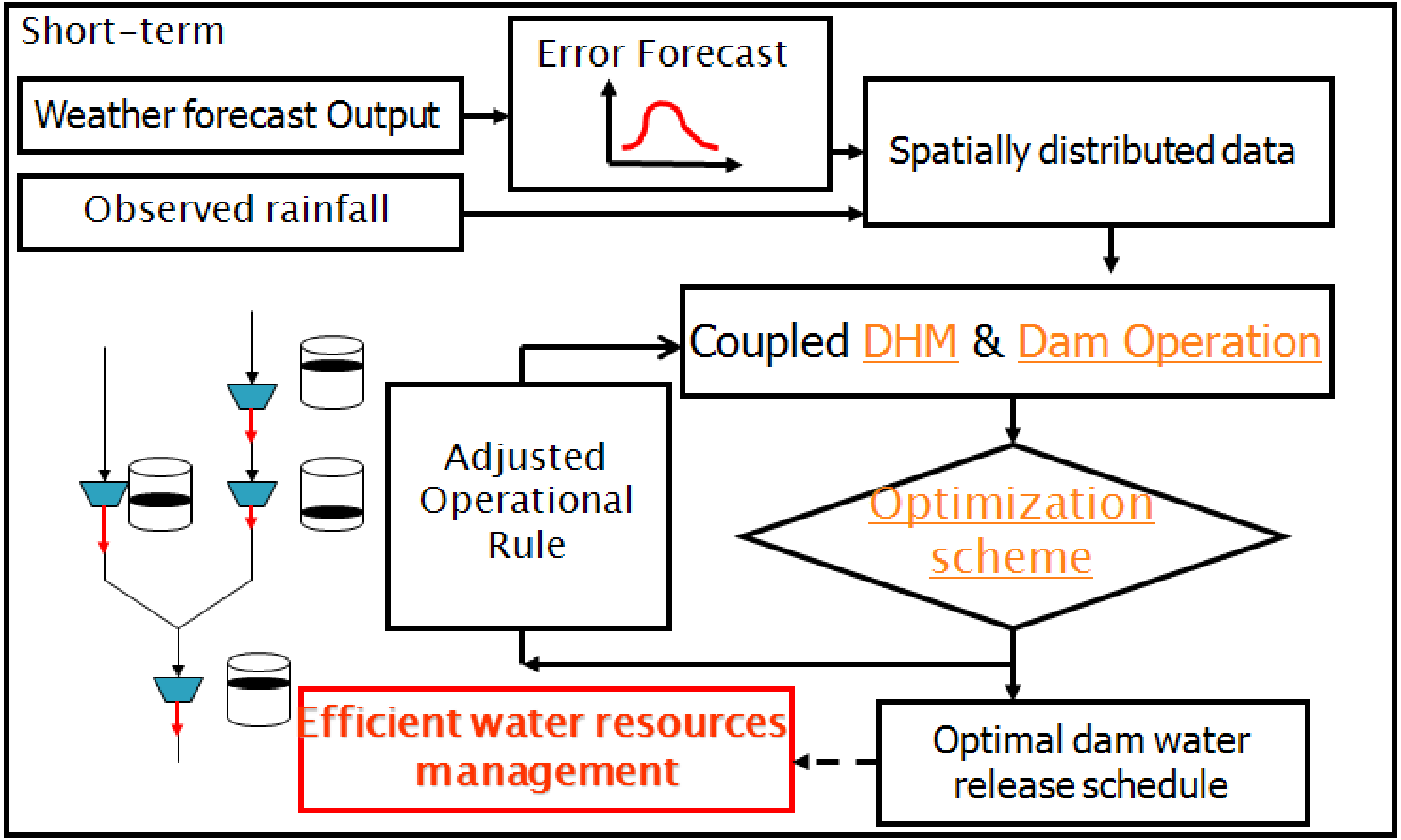


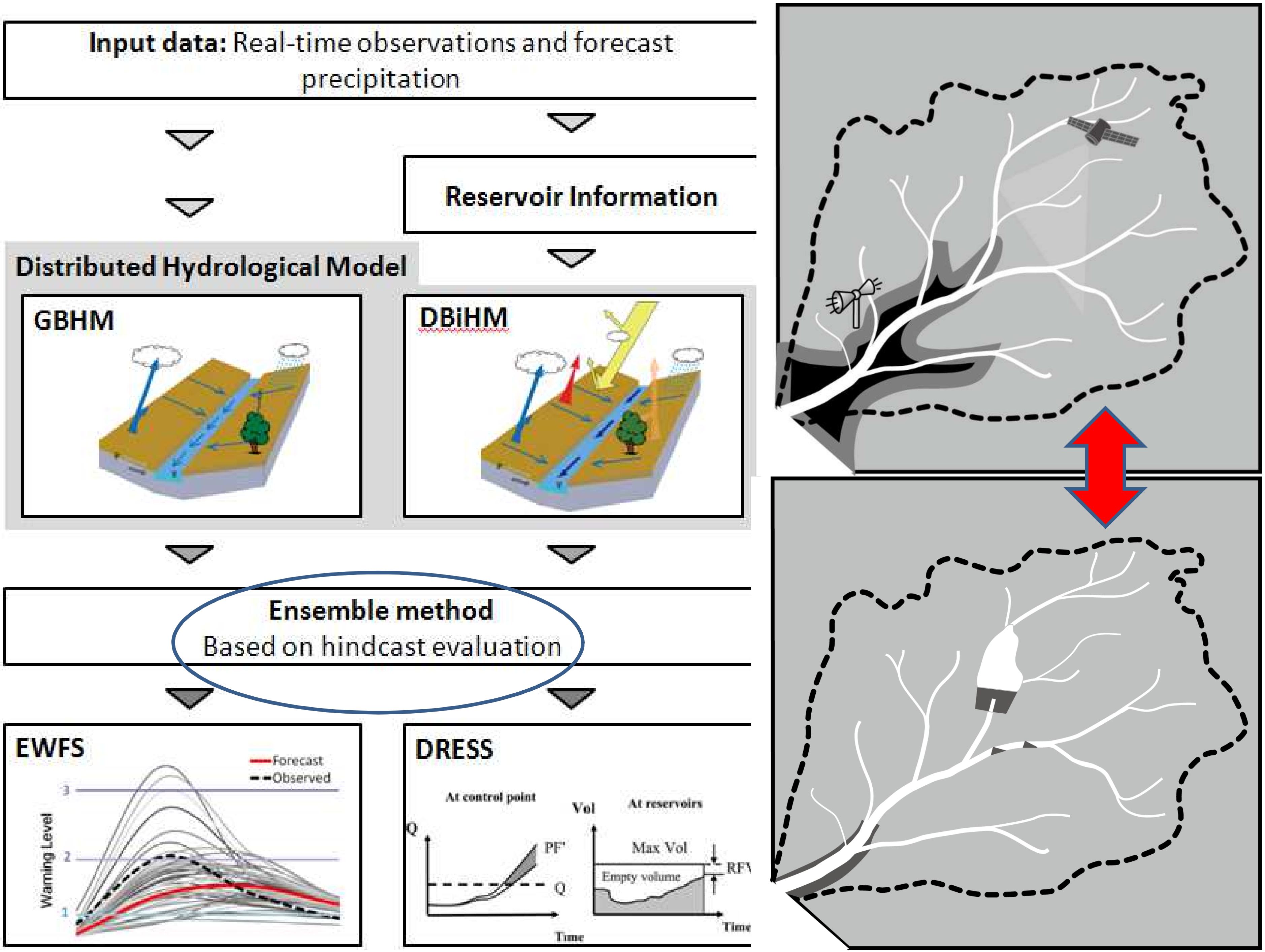


2007 Oct 1st 20:00 ~ 2nd 15:00
2007 Oct 15th 14:00 ~ 16th 2:00
2007 Oct 30th 10:00 ~ 17:
Q [m3/s]
0
500
1000
1500
2000
2500
0
10
20
30
Precipitaton [mm/h]
1
4
7
10
13
16
19 [h]
1
3
5
7
9
11
13
1
2
3
4
5
6
7
2008 Oct 24th 20:00 ~ 25th 12:00
2008 Oct 27th 20:00 ~ 28th 9:00
Q [m3/s]
0
500
1000
1500
2000
2500
0
10
20
Precipitaton [mm/h]
1
4
7
10
13
16 [h]
1
4
7
10
13 [h]

ID	Fig.	Period					Nash coefficient		Growth rate error [%]	
		Year	Month	From	To	Hours	Rain gauge	Hybrid	Rain gauge	Hybrid
1	5 a	2007	October	1st 20:00	2nd 15:00	20	0.64	0.88	5.7	7.0
2	5 b			15th 14:00	16th 2:00	13	-1.1	0.65	18	10
3	5 c			30th 10:00	30th 17:00	9	0.95	0.99	18	8.3
4	6 a	2008	October	24th 20:00	25th 12:00	17	0.71	0.92	20	19
5	6 b			27th 20:00	28th 9:00	14	0.53	0.97	36	18
Mean						14.6	0.35	0.88	20	12

Dam Operation Optimization





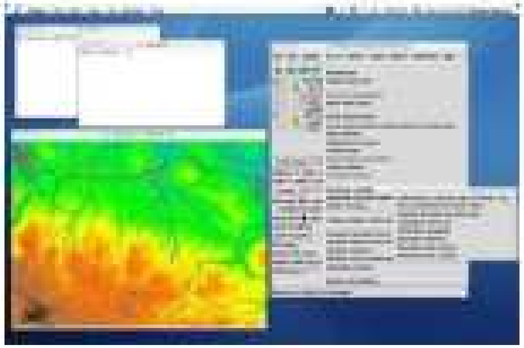
Input data: Real-time observations and forecast precipitation
Reservoir Information
Distributed Hydrological Model
GBHM
DBiHM
Ensemble method
Based on hindcast evaluation
EWFS
Forecast
Observed
Warning Level
3
2
1
DRESS
At control point
Q
PF'
Q
Time
At reservoirs
Vol
Max Vol
Empty volume
Time

NEW!

FREE!

Introduction to Watershed delineation using GRASS GIS

- How to download, install and launch GRASS
- How to set a location for map projection
- Watershed delineation and river network

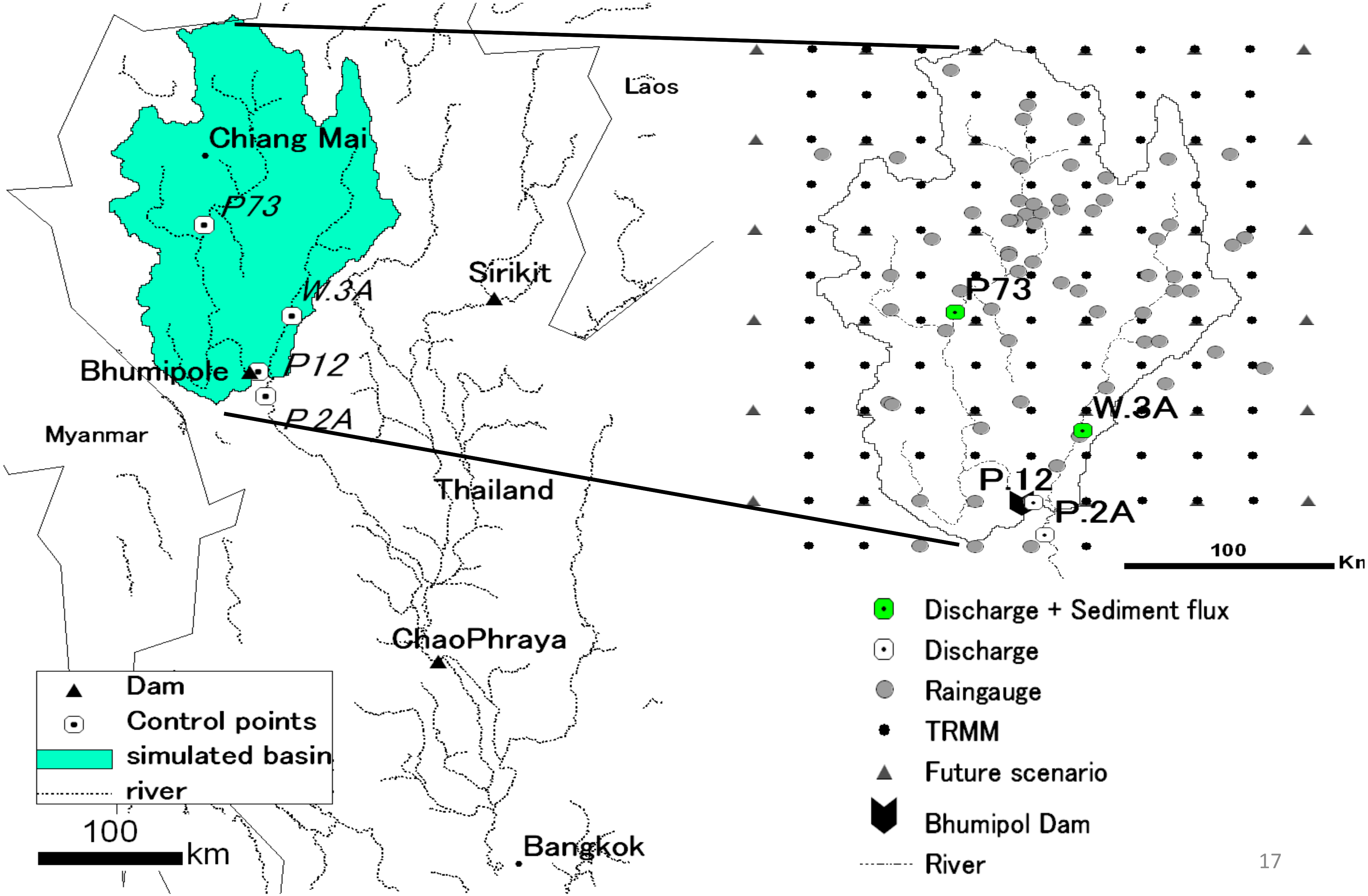


Topic 2: Sediment

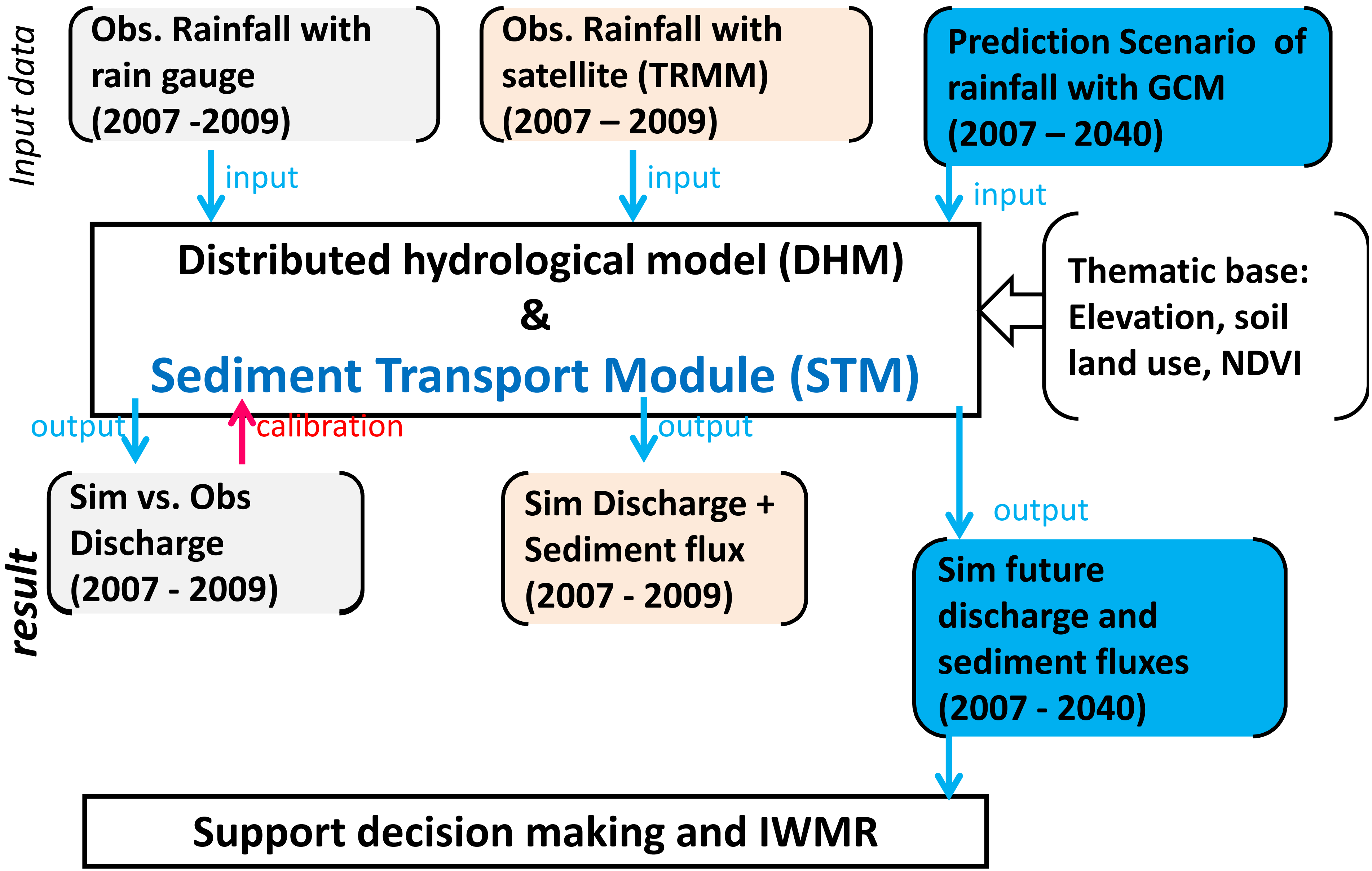
Projection of flow and sediment load in Chao Phraya River basin and its implications for integrated basin management

Oliver SAAVEDRA, Tetsuya OGATA,
Chihiro YOSHIMURA, Kazuki TANUMA ,
Winai LIENGCHARERNSIT,Yukiko HIRABAYASHI

Location of gauges

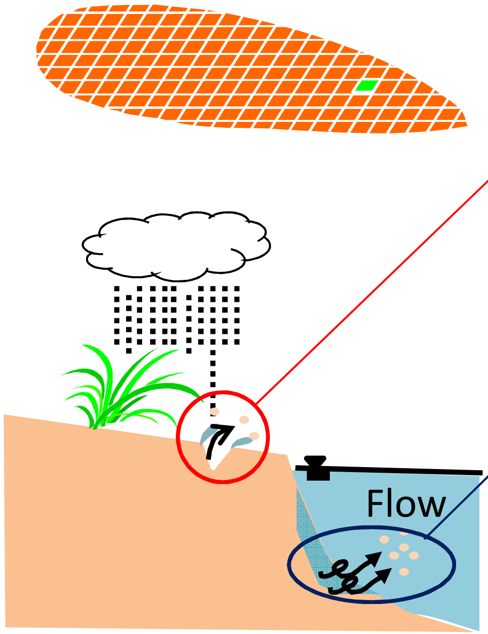


Approach



Input data
Obs. Rainfall with rain gauge (2007 -2009)
Obs. Rainfall with satellite (TRMM) (2007 – 2009)
Prediction Scenario of rainfall with GCM (2007 – 2040)
input
input
input
Distributed hydrological model (DHM)
&
Sediment Transport Module (STM)
Thematic base: Elevation, soil land use, NDVI
output
calibration
output
output
result
Sim vs. Obs Discharge (2007 - 2009)
Sim Discharge + Sediment flux (2007 - 2009)
Sim future discharge and sediment fluxes (2007 - 2040)
Support decision making and IWMR

Sediment yield at each computing grid



Rain drop erosion

$$D_R = (1 - C_g) \cdot I \cdot e^{-h}$$

Canopy ratio (C_g) *Rain intensity* (I) *Surface water depth* (h)

Flow detachment

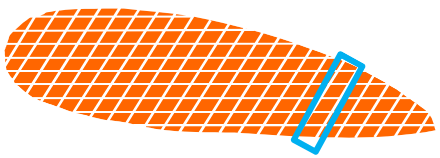
$$D_F = K_f \left(\frac{\tau}{\tau_c} - 1 \right)$$

Hydraulic shear stress (τ) **Critical hydraulic shear stress** (τ_c)

Sediment yield (at each grid)

$$e = D_R + D_F$$

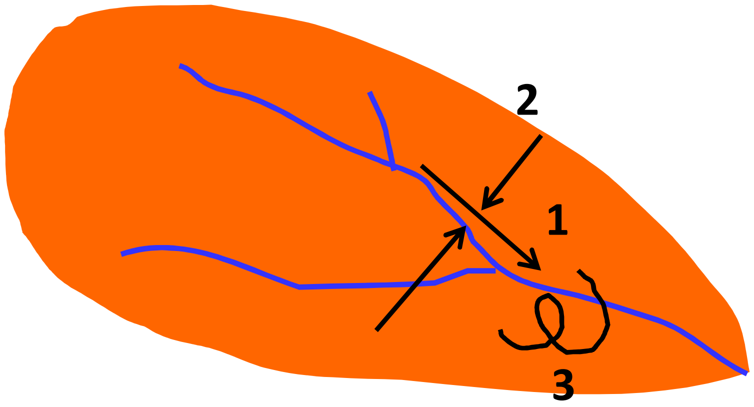
Sediment yield within flow intervals



Sediment yield (in each flow interval)

$$sslin = \sum_{1}^{ngrid} e$$

Sediment transport within river network



- Sim sediment yield @ grids are input
- Discharge and velocity simulated in DHM is input
- Erosion and deposition in river sections are estimated

$$\frac{\partial Q \cdot C_S}{\partial x} + \frac{\partial Q \cdot C_S / V}{\partial t} = sslin + DF_{river}$$

Discharge, Velocity in river section

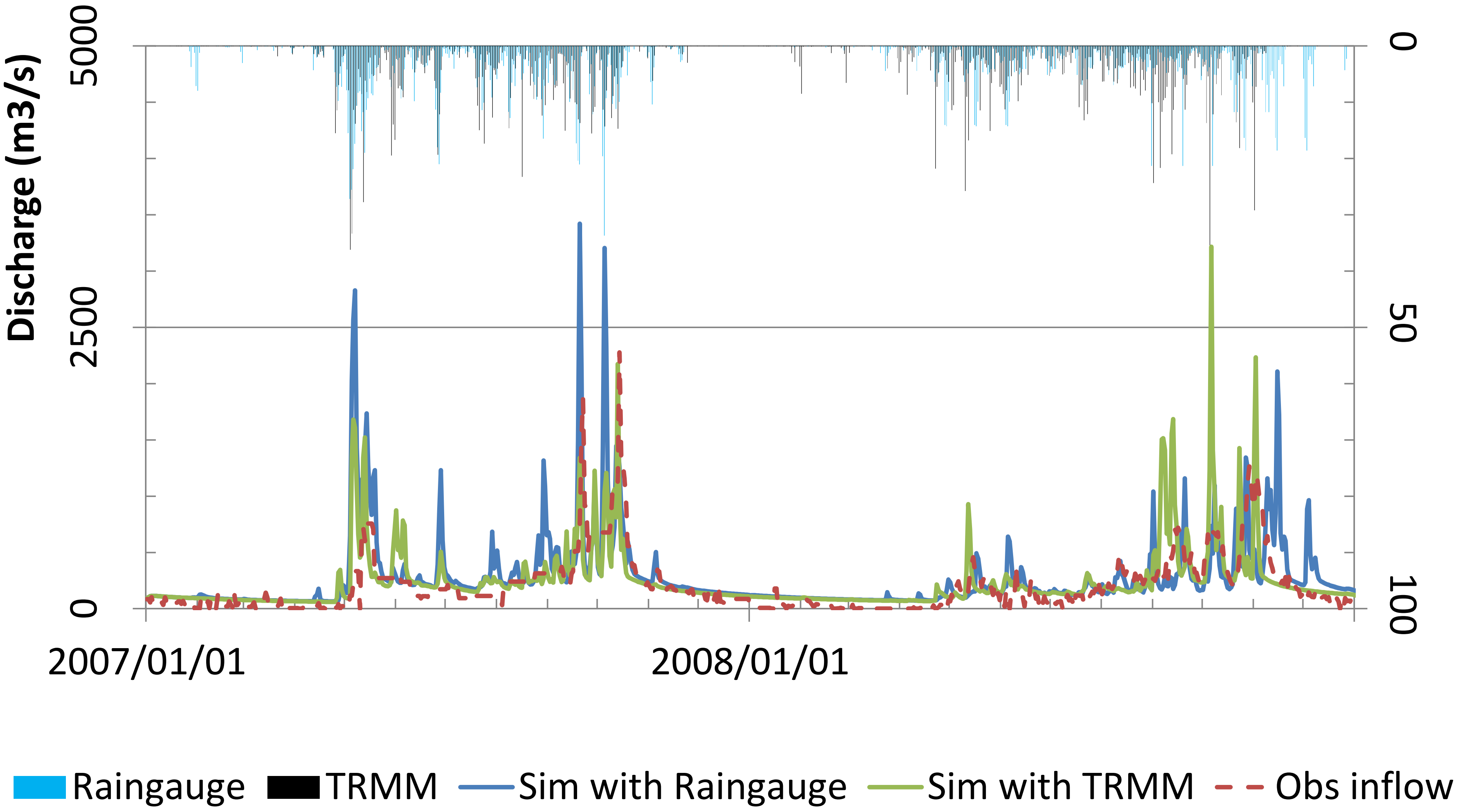
Sediment Concentration

1. Sediment Transport

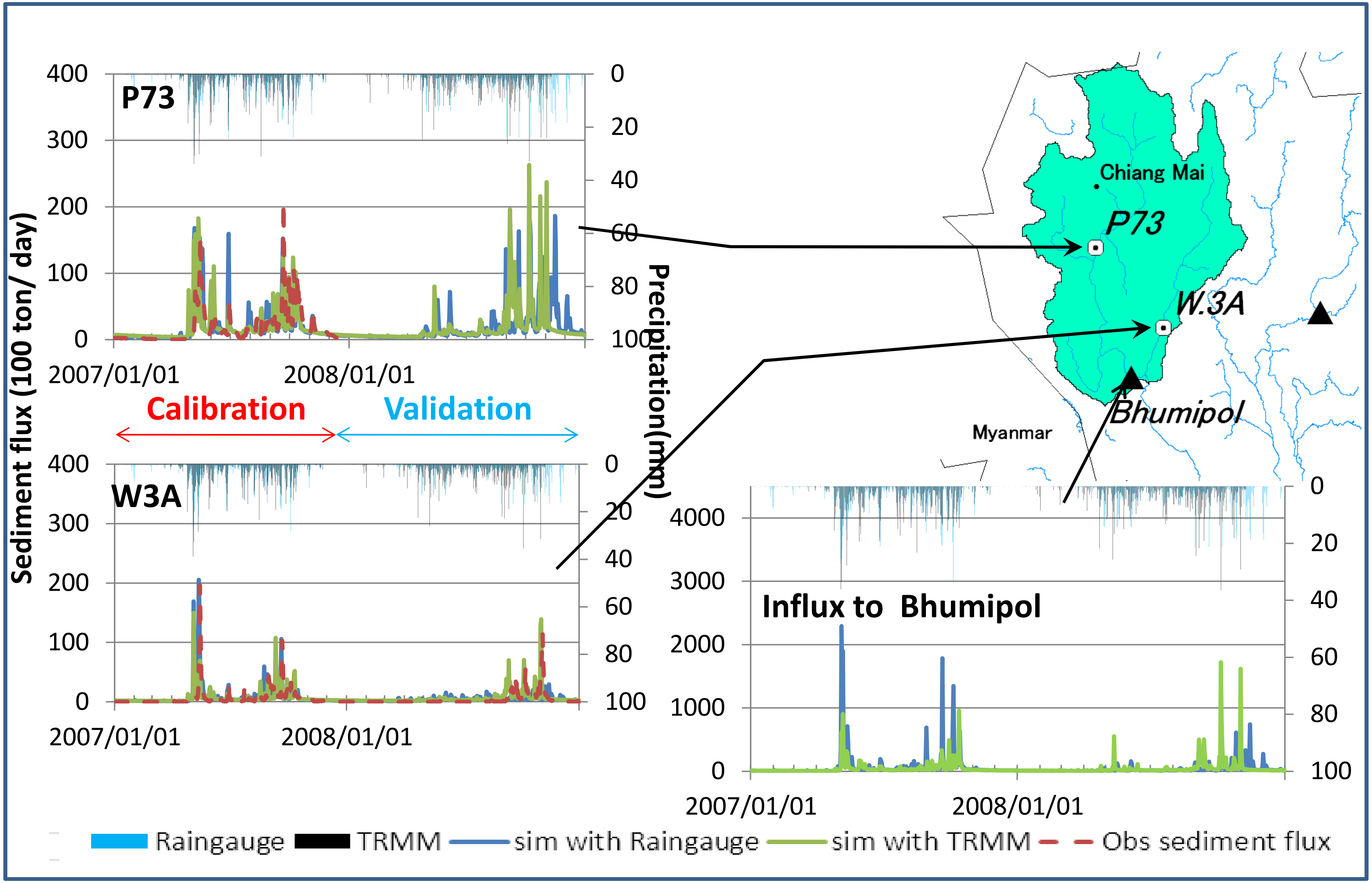
2. Sediment yield in each grid

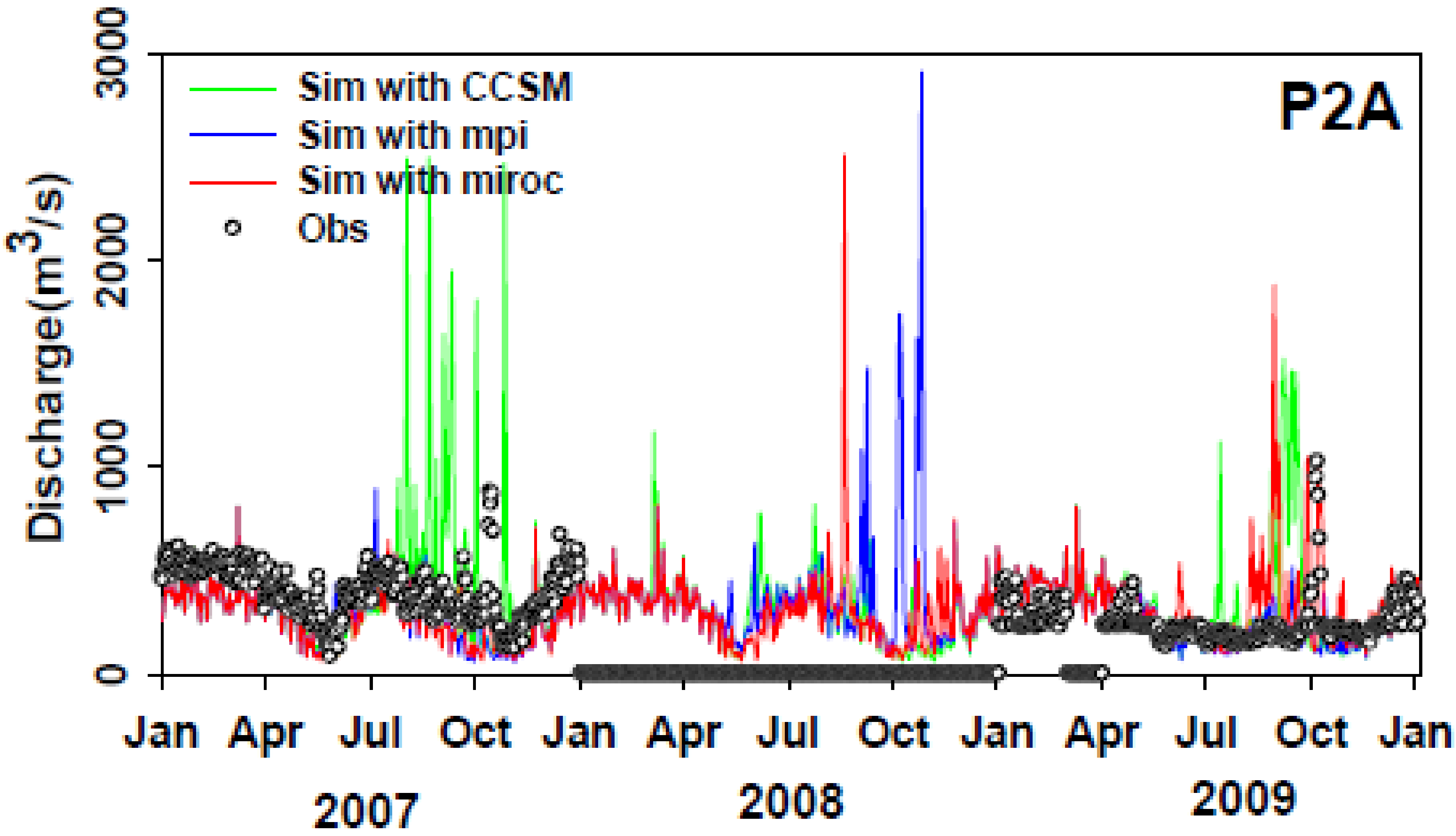
3. Erosion & Deposition in river section

Results of river discharge

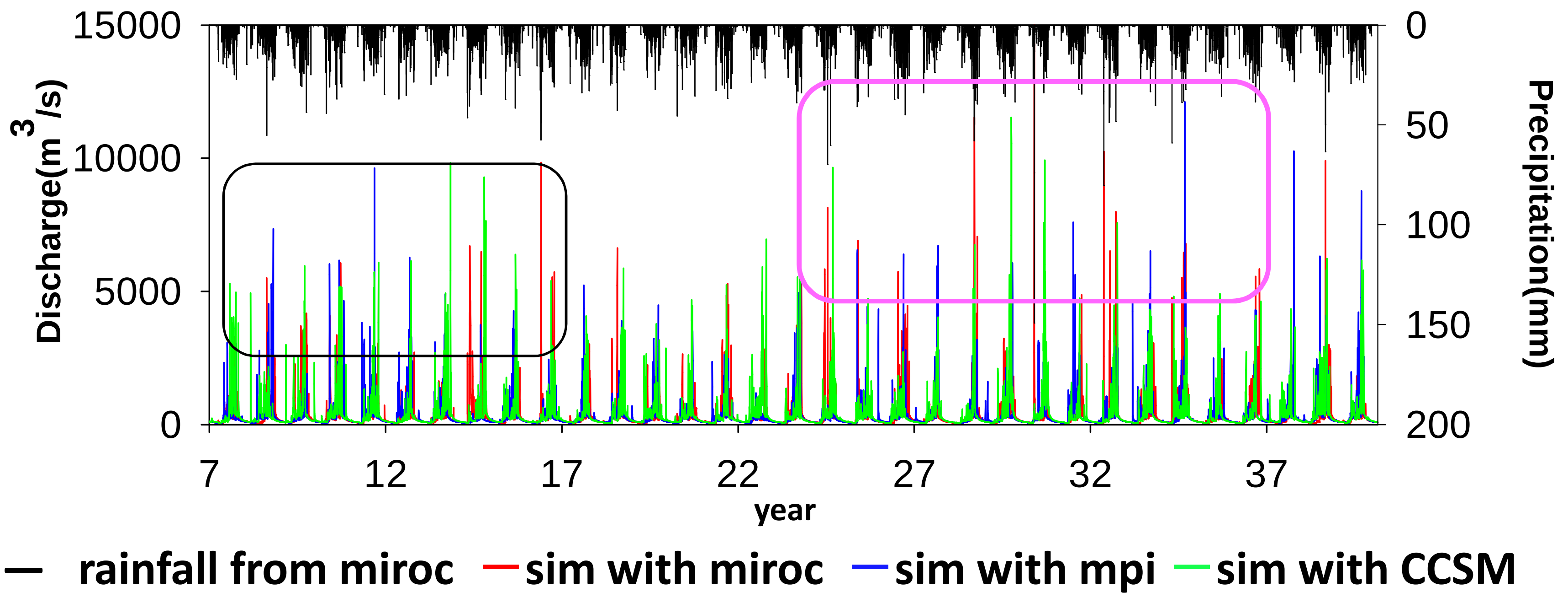


Results of sediment flux




Sim with CCSM
Sim with mpi
Sim with miroc
Obs
P2A
Discharge(m3/s)
0
1000
2000
3000
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Jan
2007
2008
2009

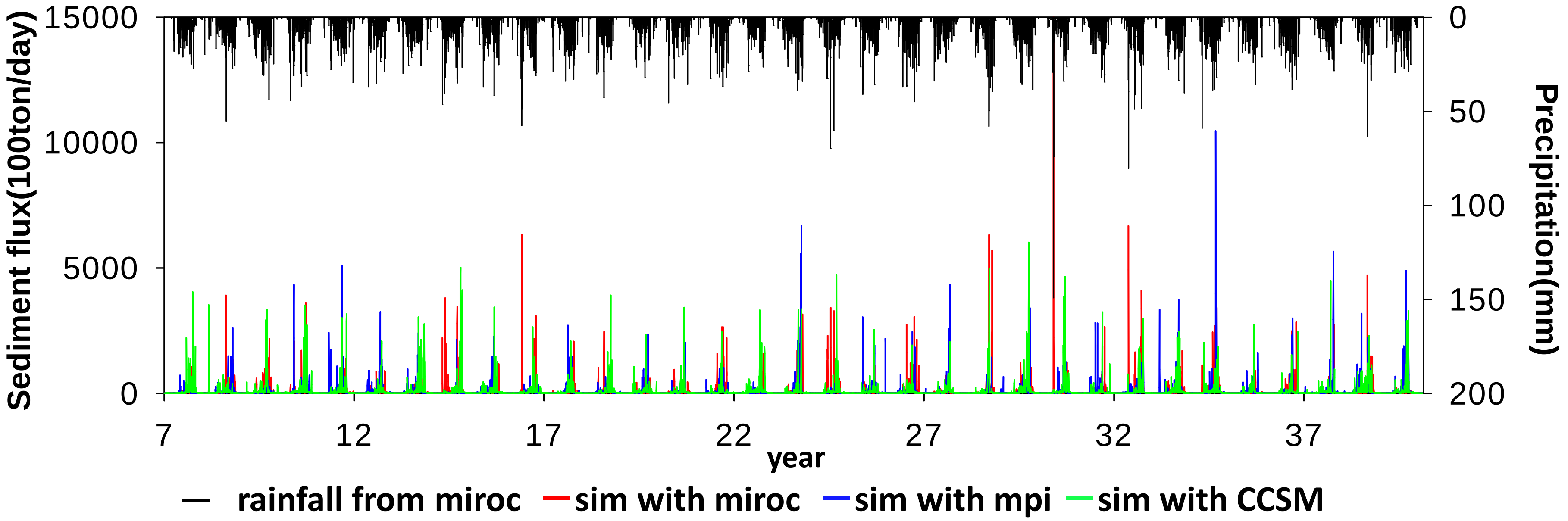
Predicted inflow with GCM outputs to Bhumipol dam



• Three types of GCM outputs were input to DHM.

•15 years later (from 2025 to 2035), river flow is likely to have higher variance than around 2012.

Predicted sediment influx to Bhumipol dam

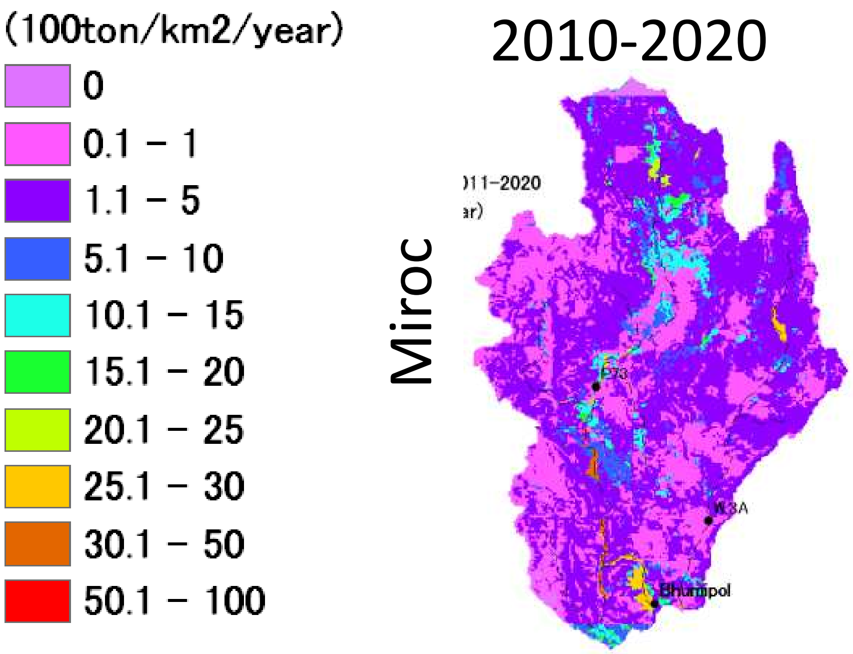


- 0.5 to 1.5 million m^3 sediment are expected to be accumulate in Bhumipol dam reservoir annually.
- The annual accumulated sediments are much less than the reservoir capacity (13,462 million m^3).
- Therefore impact of sedimentation might not so critical.

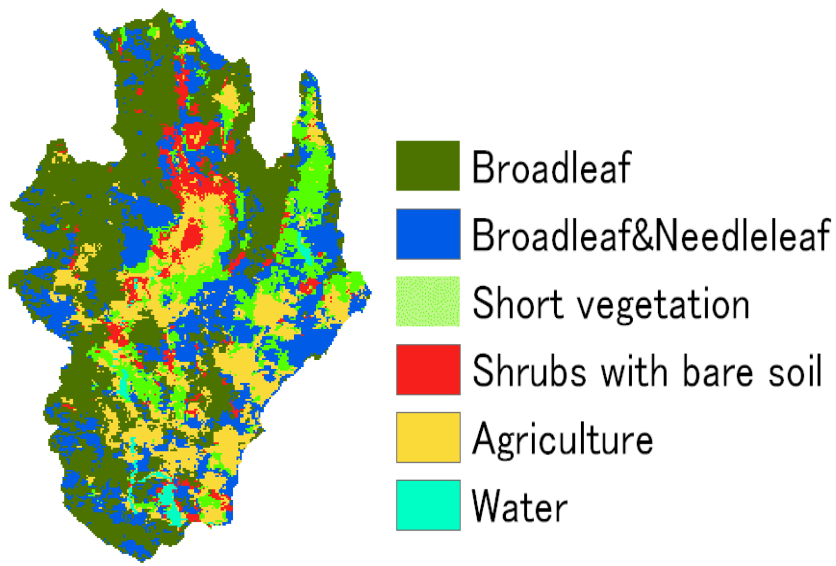
Future spatial distribution of sediment yield

- Decade average of annual accumulated sediment yield in each grid was calculated with GCM output.
- The sediment yield in each grid highly related to land characteristic.

2010-2020



Land use characteristic

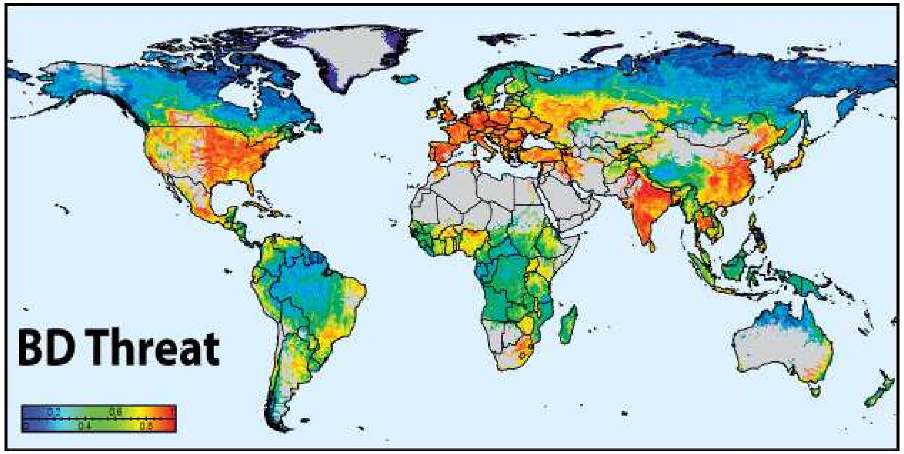


Topic 3: Fish population

Development of Basin-Scale Fish Distribution Model and its Application to Sagami River for Habitat Assessment

Oliver SAAVEDRA, Pengzhe SUI, Akito IWASAKI, Chihiro YOSHIMURA

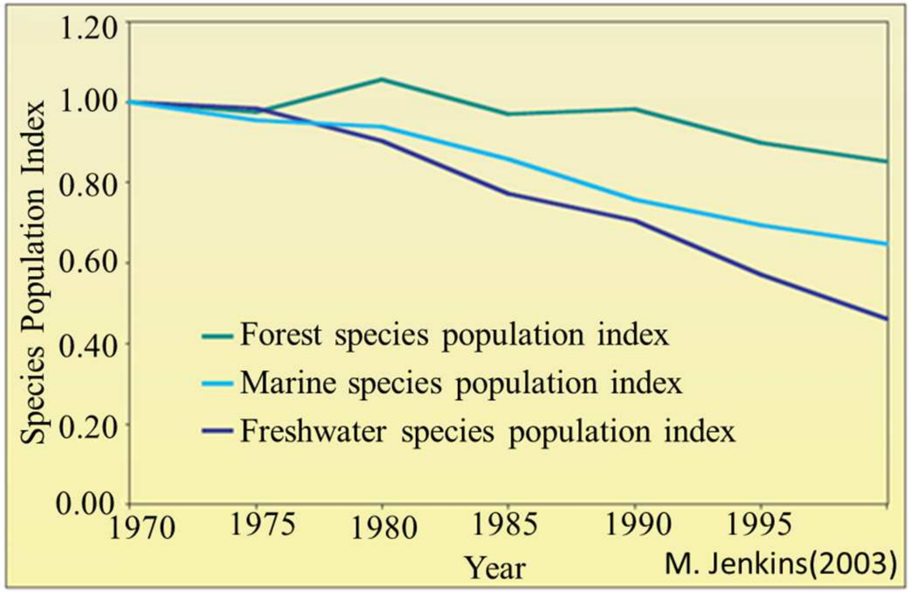
Background –biodiversity decline



Vorosmarty, C. J., et al. (2010). "Global threats to human water security and river biodiversity." Nature 467(7315): 555-561.

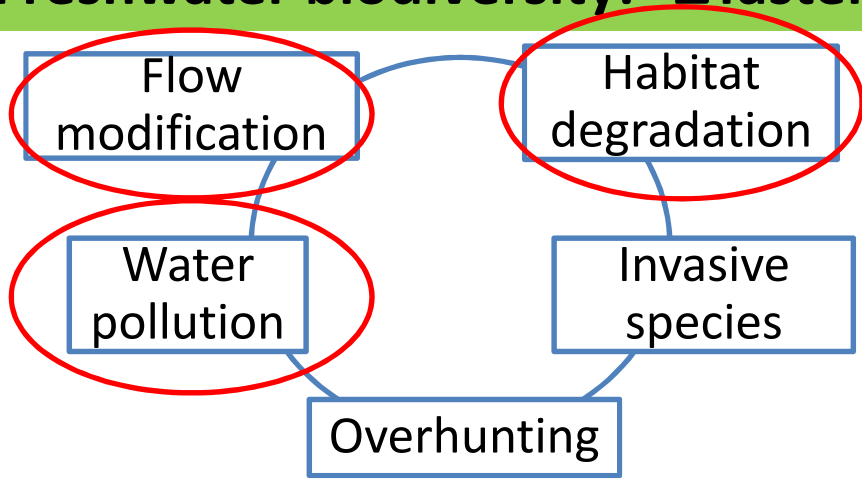
Multiple environmental issues

- Endanger **65 percent** of world's river habitats
- Put **thousands of** aquatic wildlife species at risk



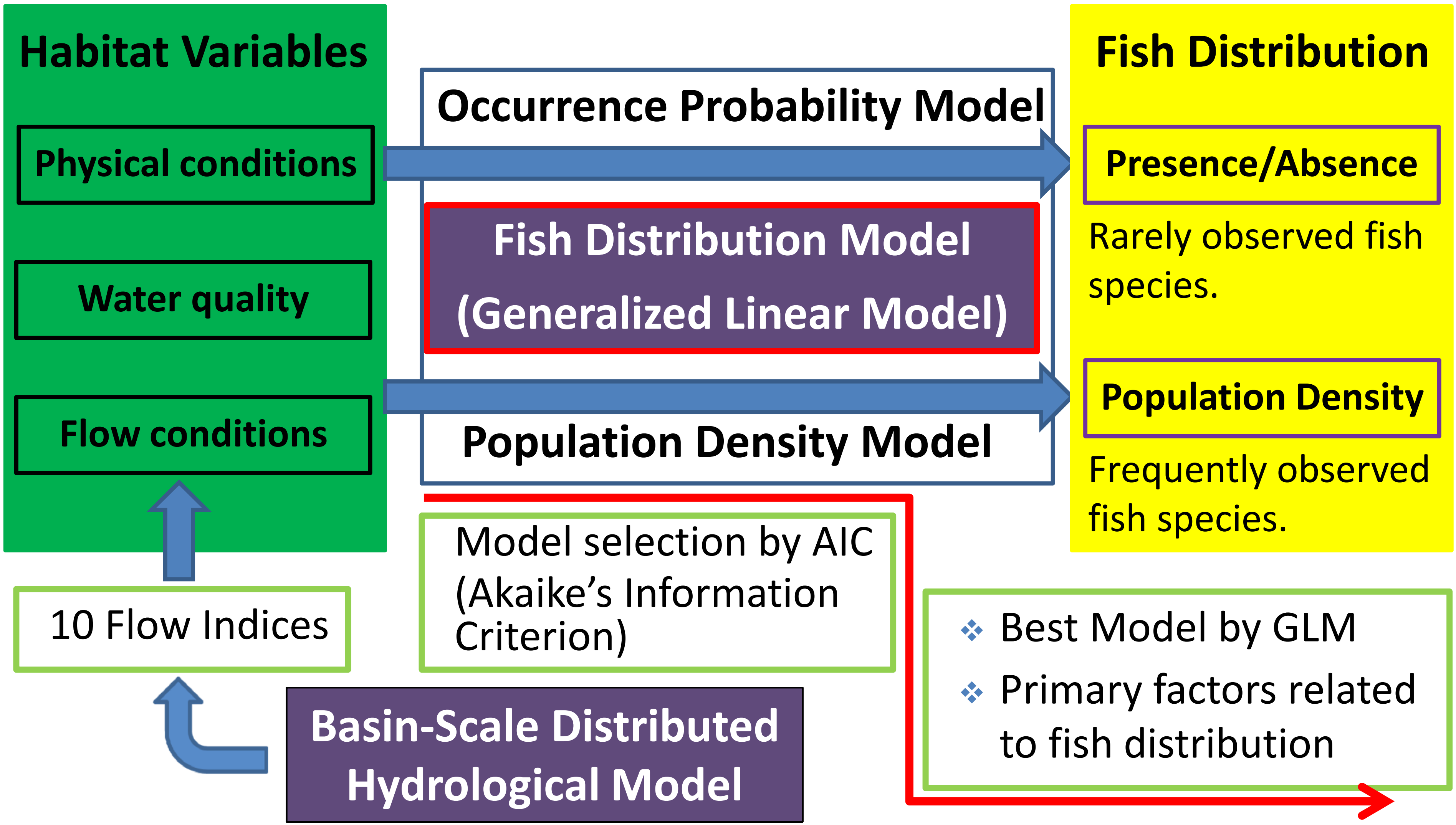
Jenkins, M. (2003). "Prospects for biodiversity." Science 302(5648): 1175-1177.

Freshwater biodiversity: ↘faster



Dudgeon, D., A. H. Arthington, et al. (2006). "Freshwater biodiversity: importance, threats, status and conservation challenges." Biological Reviews 81(2): 163-182.

Development of fish distribution model for habitat assessment.



Habitat Characteristics (28)

Physical conditions (13)

- **Basin Area (BA)**
- **Mean Longitudinal Slope (S)**
- Max Longitudinal Slope (MS)
- Distance from Sea (DFS)
- Altitude (AL)
- River Width (RW)
- **Section Length (SL)**
- **Sinuosity Index (SI)**
- Number of Upper Dams (NUD)
- **Number of Lower Dams (NLD)**
- **Isolation Period (IP)**

River bed material

- Mean Diameter of River Bed (D50)
- Uniformity Coefficient (UC)

Water quality (5)

- Chemical Oxygen Demand (COD)
- Biochemical Oxygen Demand (BOD)
- Demand Oxygen (DO)
- Total Nitrogen (TN)
- Total Phosphorus (TP)

Flow conditions (10)

- **Annual Mean Discharge (AMD)**
- **Minimum Discharge (MID)**
- Ratio of Max/Min Discharge (RMM)
- Discharge Variance (DV)
- Spring Discharge (SD)
- Low Flow Discharge (LFD)
- High Flow Discharge (HFD)
- **Duration of Low Flow (DLF)**
- **Duration of High Flow (DHF)**
- Number of Flood (NF)

Sagami River Basin (Japan)

Sagami River

(Kanagawa and Yamanashi Prefecture)

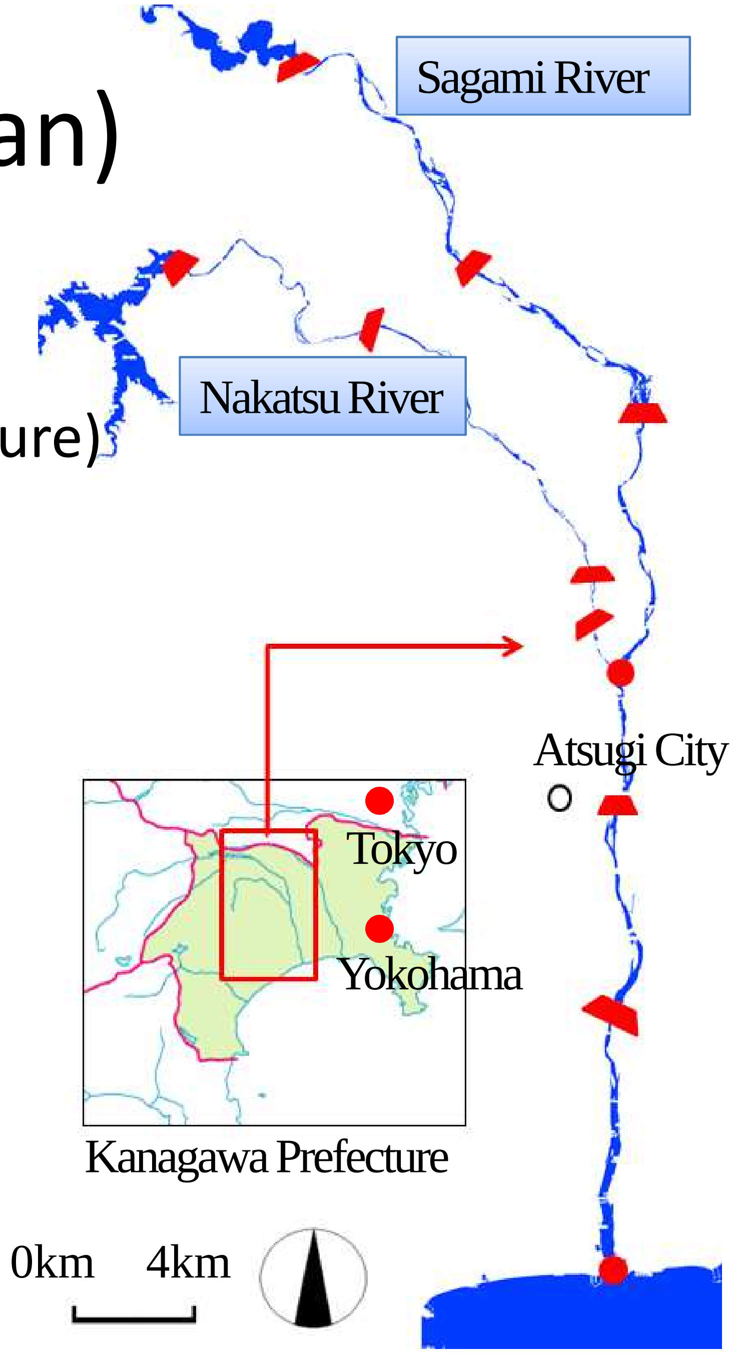
Nakatsu River

(Main tributary of Sagami River)

10 sections

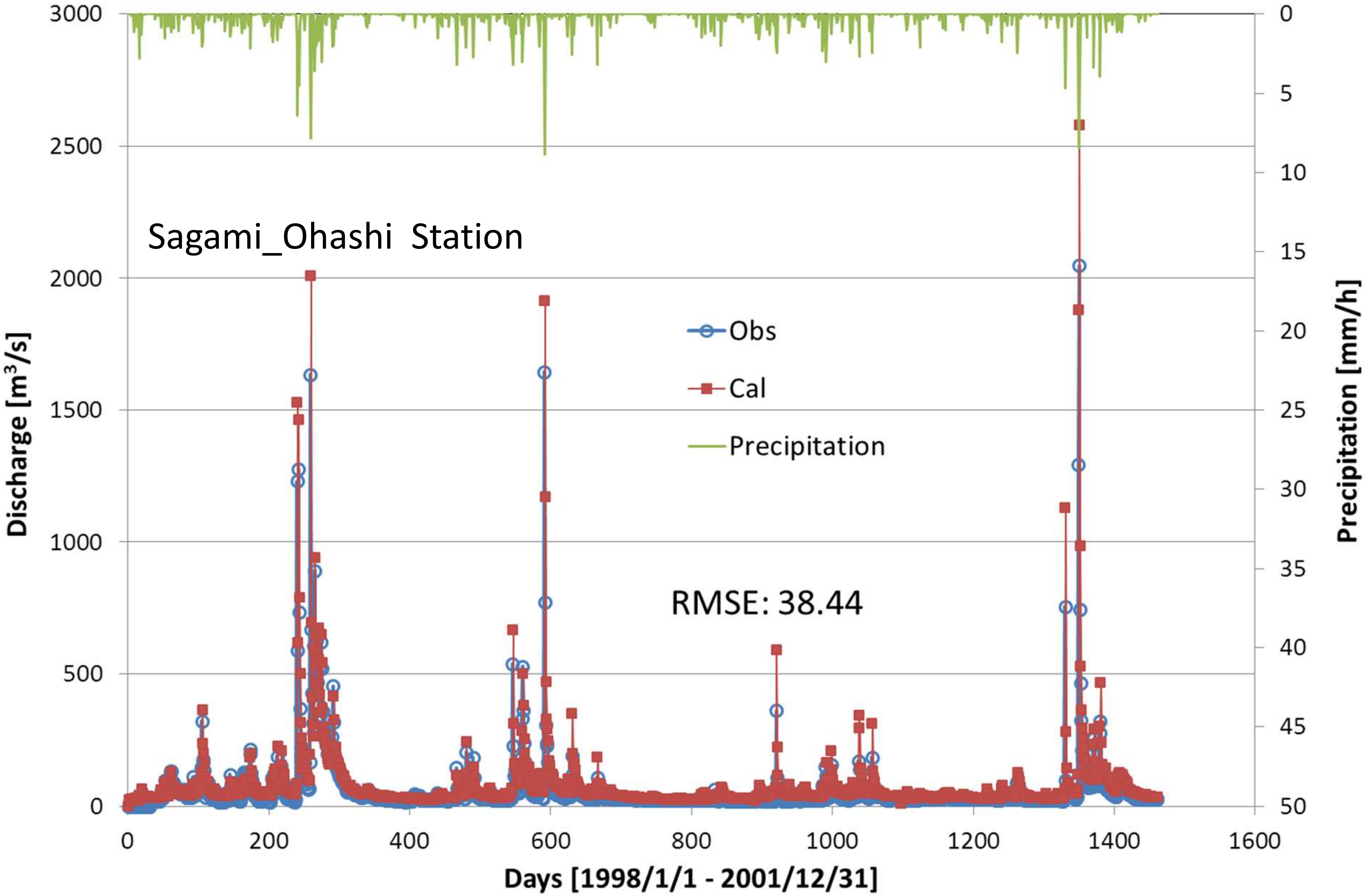
divided by…

- Dam and weir (higher than 1m)
- Junction of rivers
- Estuary



Note: All structures except Shiroyama dam and Miyagase dam have fish ladder.

Hydrological simulation results



Occurrence Probability Model - Methods

Fish Data

Presence / Absence data of **54 fish species** were collected **from 1998 to 2005**.

If fish was observed at least once in section. → **Presence**

If fish was never observed in section. → **Absence**

Model Structure

Relationship between fish data and habitat characteristics was evaluated by using **Generalized Linear Model**

$$\boldsymbol{Occurrence\ Probability} = \frac{\mathbf{1}}{\mathbf{1 + exp\left(-\left(\alpha + \sum \beta_i X_i\right)\right)}}$$

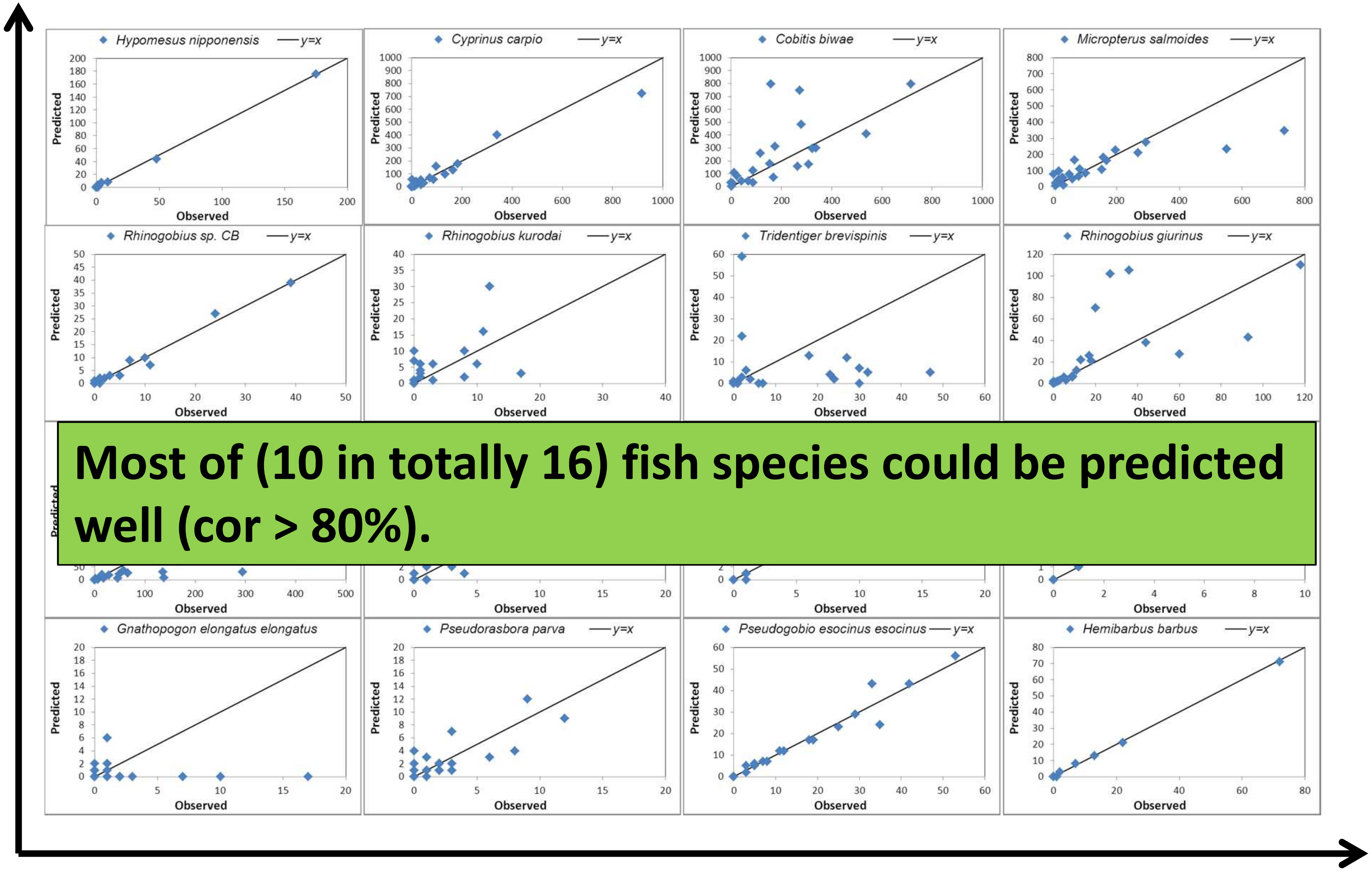
α: regression constant

β_i: regression coefficient

X_i: habitat variables

Population Density Model - Results

Predicted Fish Number

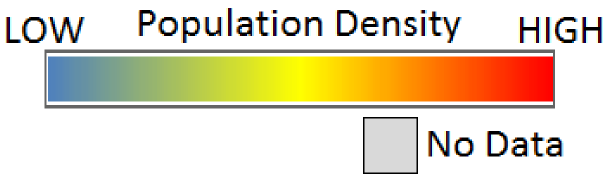


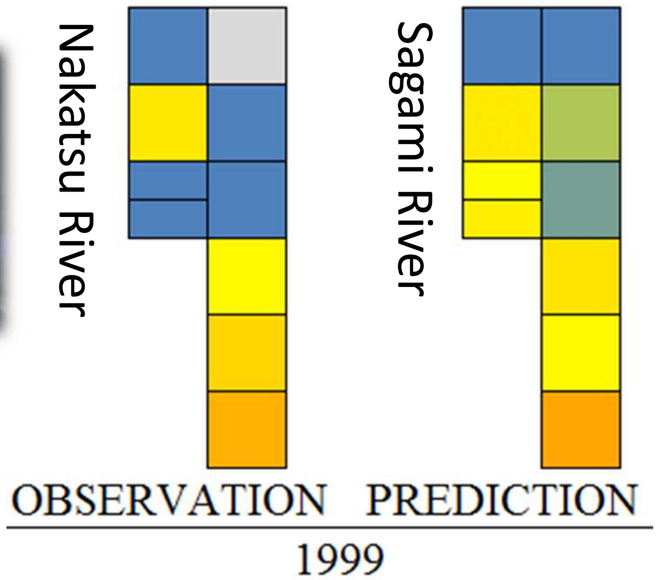
Most of (10 in totally 16) fish species could be predicted well (cor > 80%).

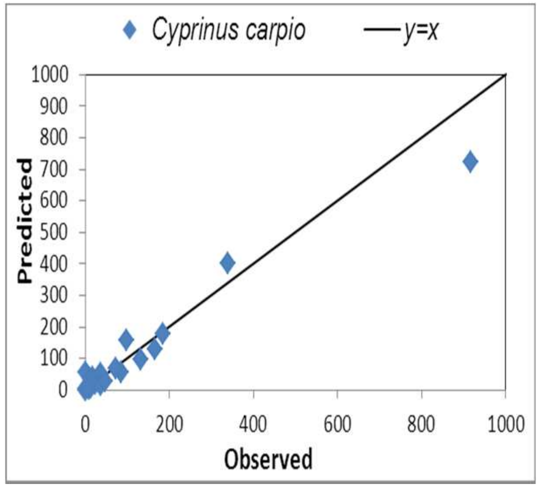
Observed Fish Number

Population Density Model - Results

Example of Density Model: *Cyprinus Carpio*







Due to SI was positively correlated to D50.

Section Length

D50

Diameter of bed materials

	(Intercept)	BA	S	SL	SI	NLD	IP	AMD	MID	DLF	DHF
Cyprinus carpio	-6.8632			0.81	-6.82					0.328	

- Number of common carp increases with increasing of **SL (Section Length)** and decreasing of **SI (Sinuosity Index)** and **DLF (Duration of low flow)**.
- Common carp like river bed with big-size-materials.

Summary

- Flood simulation:
    - GsMap used as correct interpolation
    - Structural and nonstrutural management
- Sediment yield and transport
    - Developed the module
    - Future prediction of Q and C
- Fish population
    - Link DHM with fish model
    - Fragmentation effect of structures for species

Multipurpose dam operation including:
Flood control, Sediment concentration, E-flow

Summary I

Model development

• A process based sediment approach was developed, and applied to upper Chao Phraya River basin.

•The validation result was found in close agreement with observed sediment flux from 2007 to 2009.

Future projection

• From 2025 to 2035 the variance of discharge might increase

• The annual accumulated sediment into Bhumipol Dam reservoir are found 0.5 - 1.5 million m^3/year.

• Land use types are more important for sediment yield than projected rainfall change.

Summary

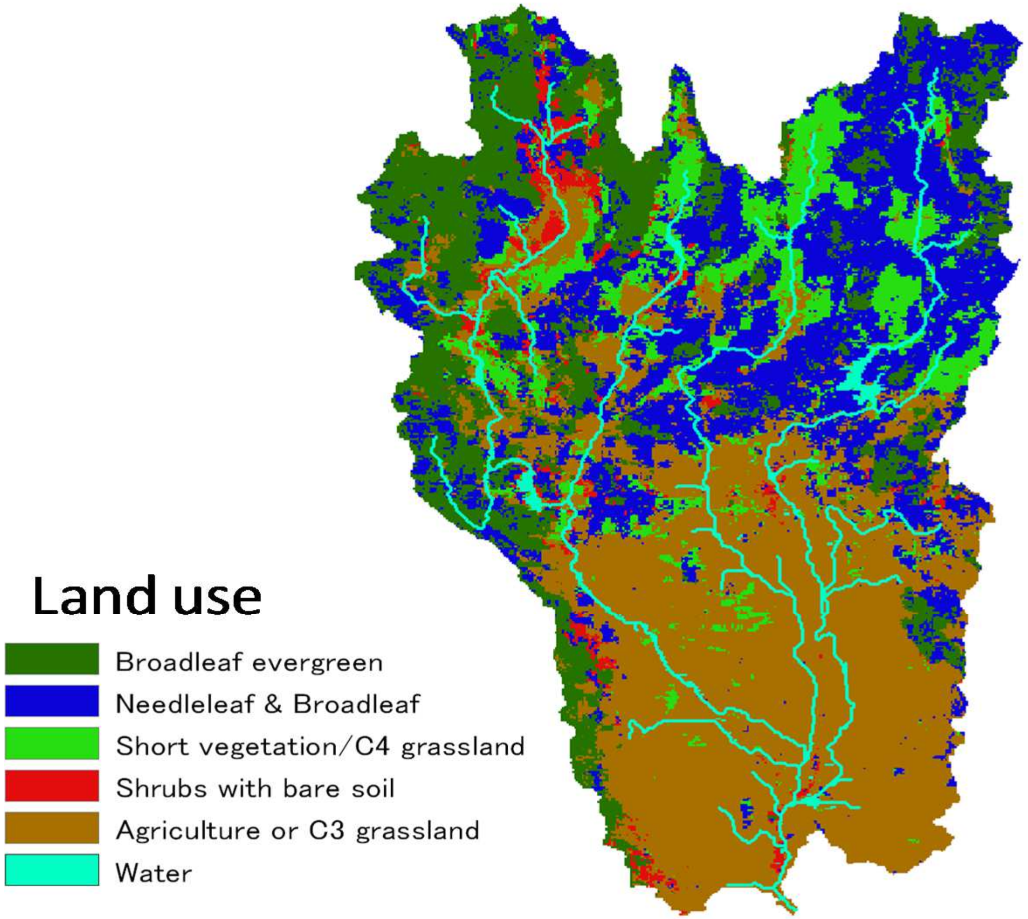
- **Simulated:**
  Presence/absence model: **53 (1 failed)** fish species;
  population density model : **all 16 fish species** fish species.

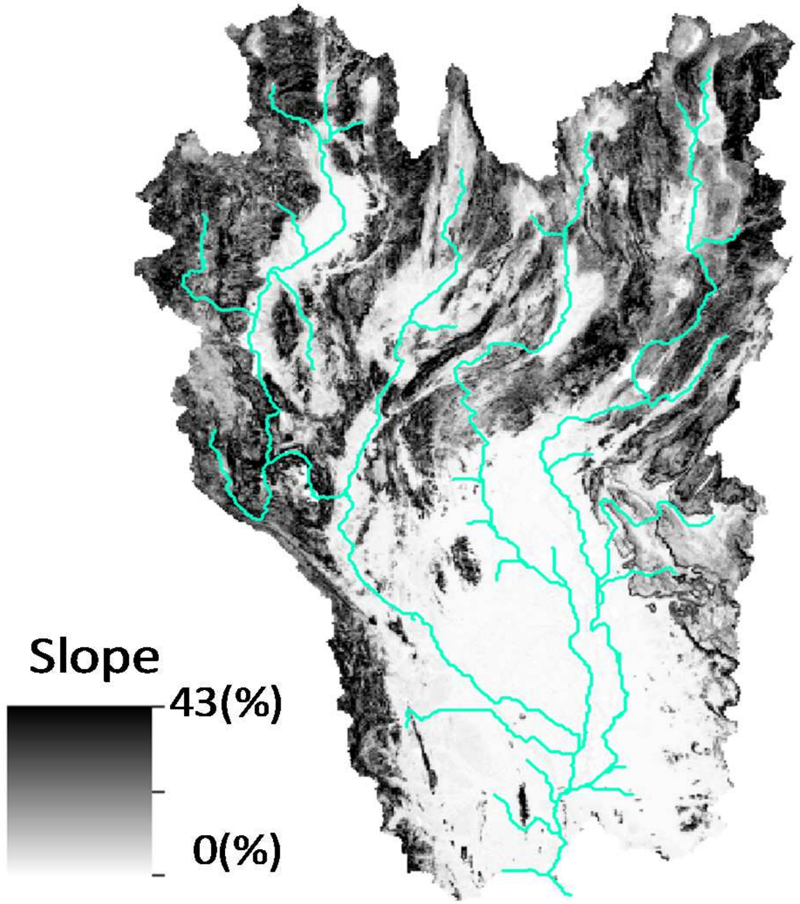
- Besides physical conditions, **flow indices** play important roles for the distribution of fish species.

- NLD is important for 27 (in totally 53) fish species, which confirmed **a negative effect of river-crossing structures, such as dams and weirs.**

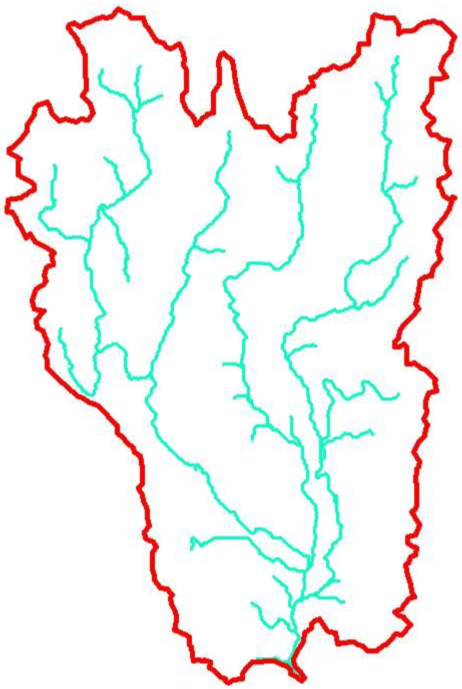
- **Sinuosity Index (SI)** seems to be an important parameter for fish distribution in Sagami River basin.

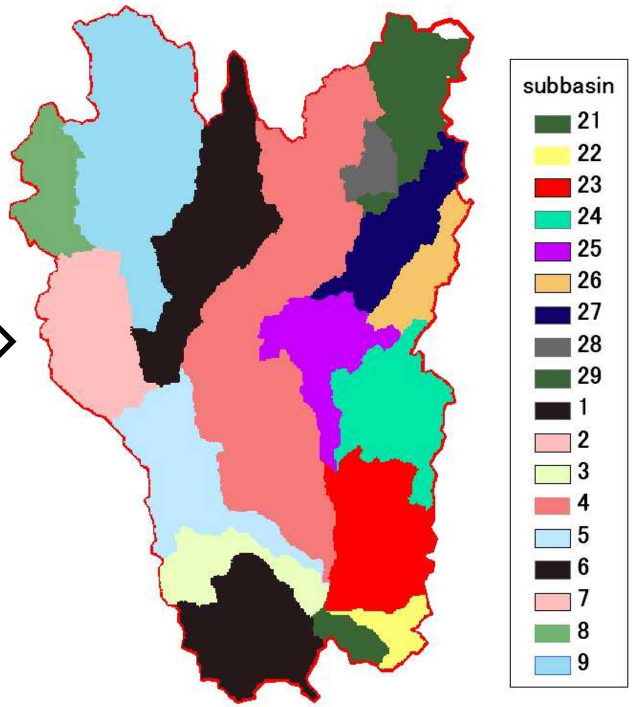
Characteristics of the basin

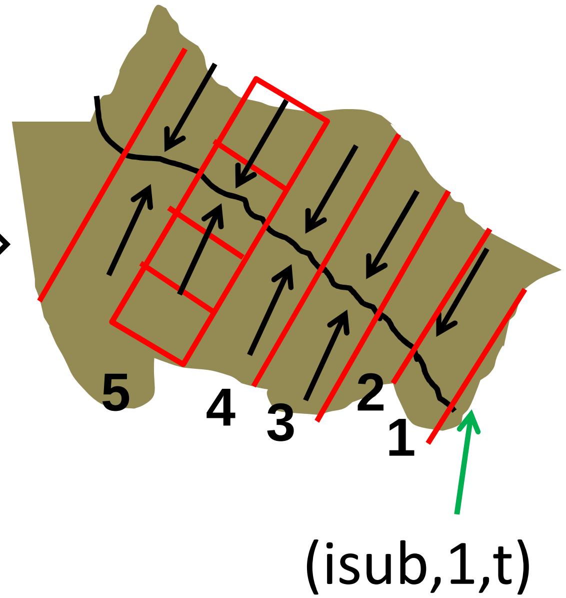




Computing elements







Generally
Q(x,y,t)

Classify by river length
(x,y)→(isub,iflow)

Q(isub,iflow,t)

Spatial distribution of sediment yield