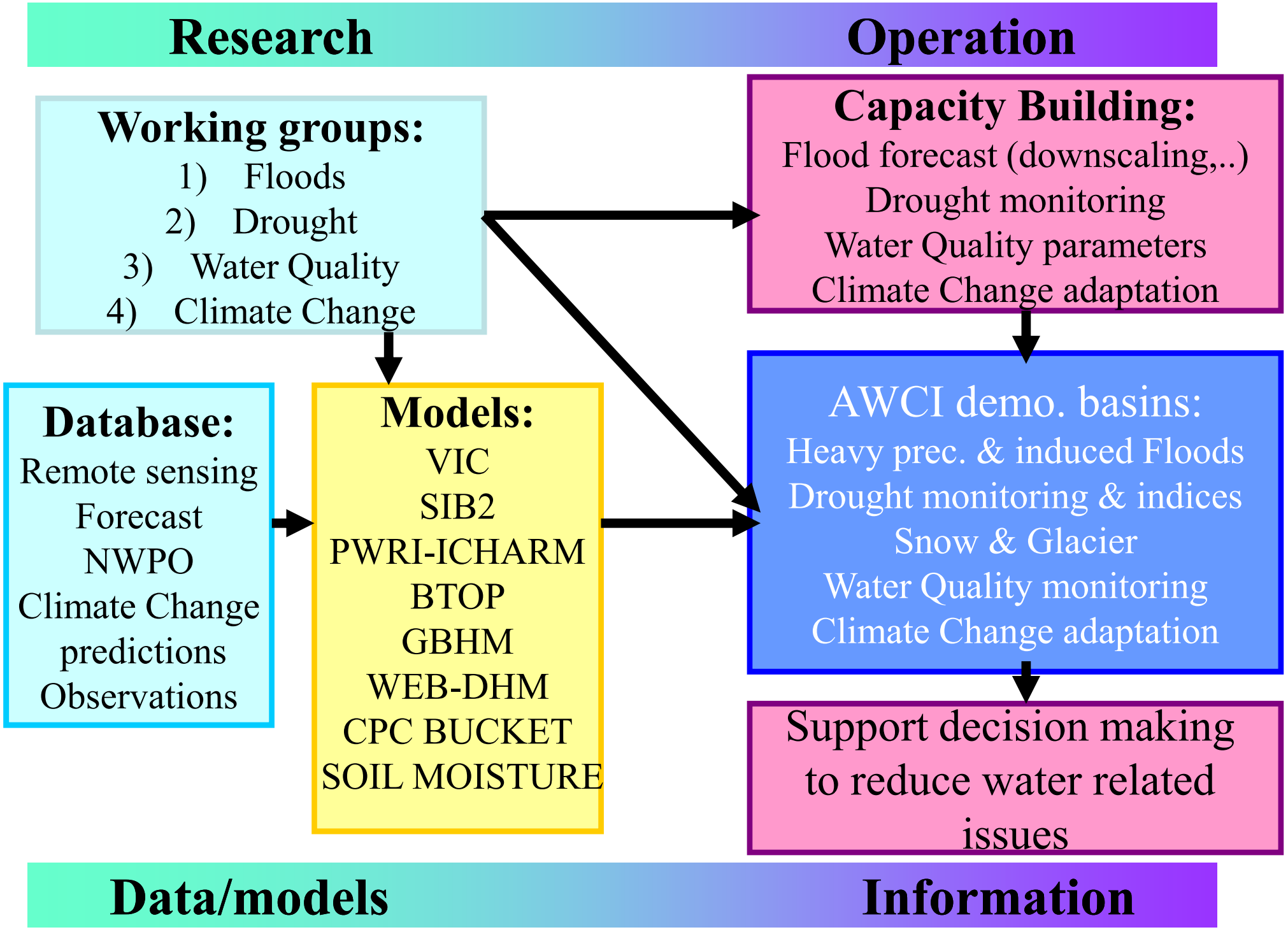
Decision support systems using optimization algorithms at AWCI demo basins

Oliver Saavedra[1)] and Toshio Koike[2)]

Department of Civil Engineering

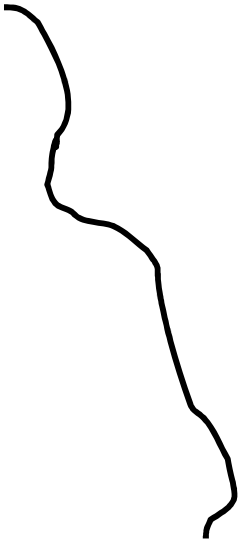
1) Tokyo Institute of Technology

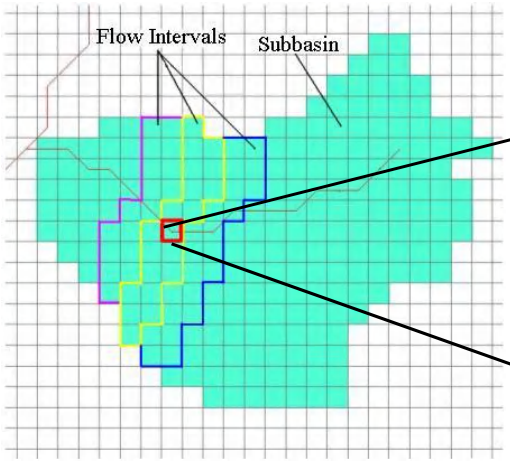
2) University of Tokyo


Research
Operation
Working groups:
1) Floods
2) Drought
3) Water Quality
4) Climate Change
Capacity Building:
Flood forecast (downscaling,..)
Drought monitoring
Water Quality parameters
Climate Change adaptation
Database:
Remote sensing
Forecast
NWPO
Climate Change predictions
Observations
Models:
VIC
SIB2
PWRI-ICHARM
BTOP
GBHM
WEB-DHM
CPC BUCKET
SOIL MOISTURE
AWCI demo. basins:
Heavy prec. & induced Floods
Drought monitoring & indices
Snow & Glacier
Water Quality monitoring
Climate Change adaptation
Support decision making to reduce water related issues
Data/models
Information

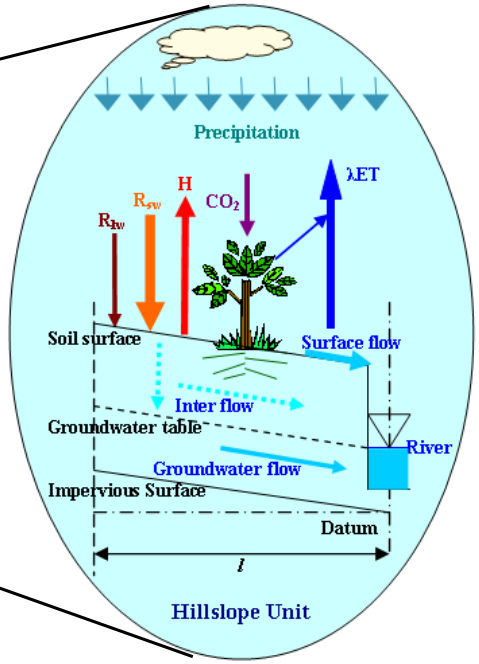
Regional & basin interaction

Regional hydrological & land surface models

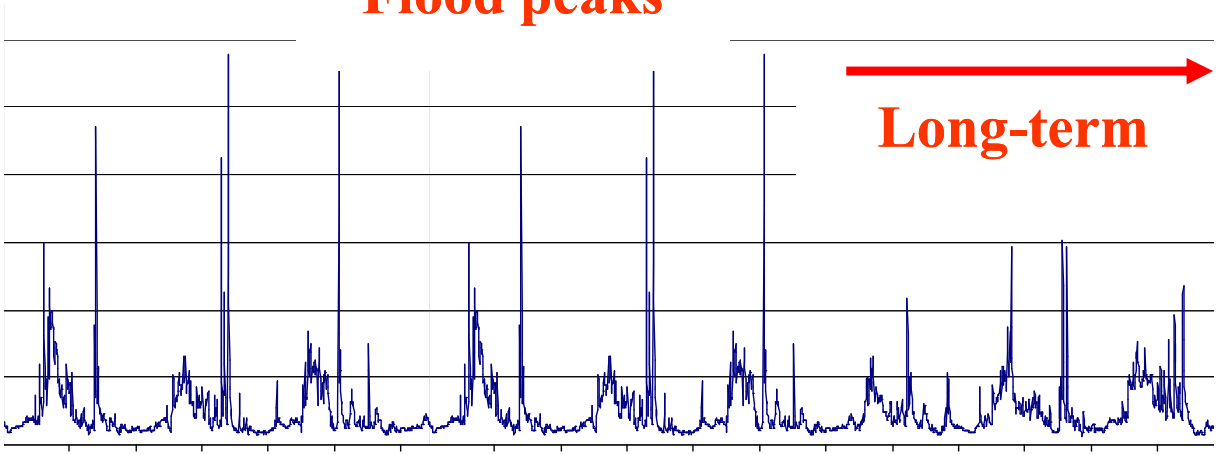




Distributed Biosphere Hydrological Model



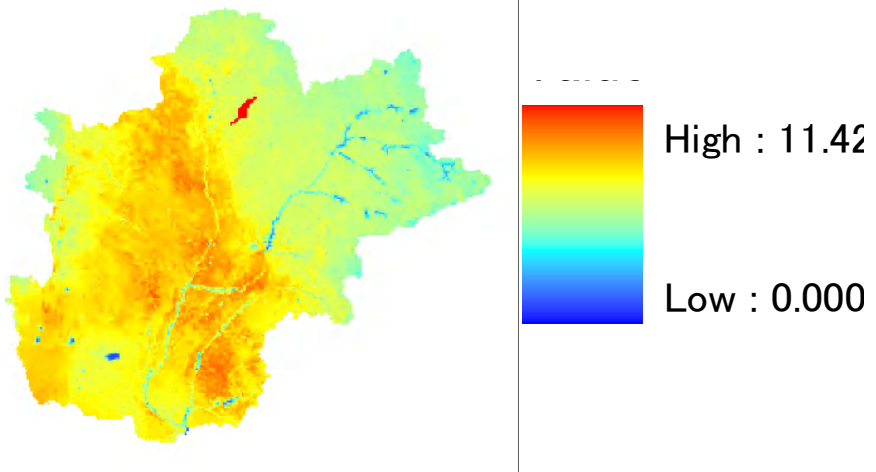
Flood peaks



Long-term

Low flow

Wang, Koike et al., 2009



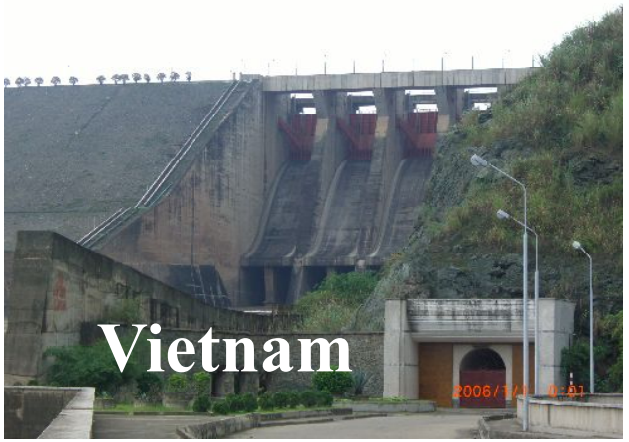
Floods in South-East-Asia

- Heavy rainfall brings expected rainfall for agriculture but they might also turn into floods causing damages.

Need 1: Emission of flood warning to perform evacuation timely

- Basins with existing gated dams when operated effective and jointly they are able to reduce flood damage dramatically.

Need 2: Dam release decision to reduce flood peaks and store volume for water-use



System Development under Floods

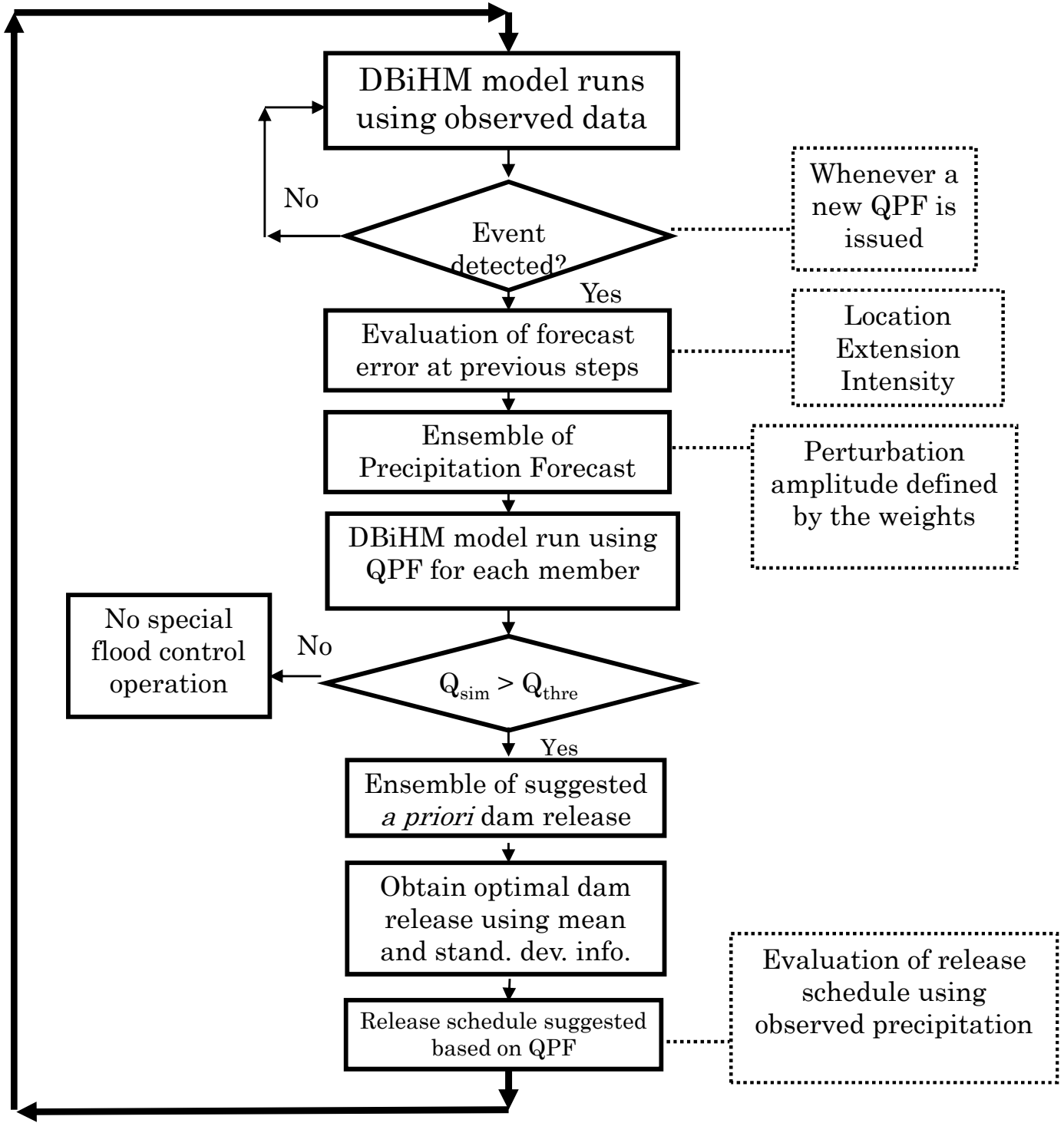
- Dam Release Support System (DRESS)

  Goal: Dam release decision support to reduce flood peaks and store volume for water-use

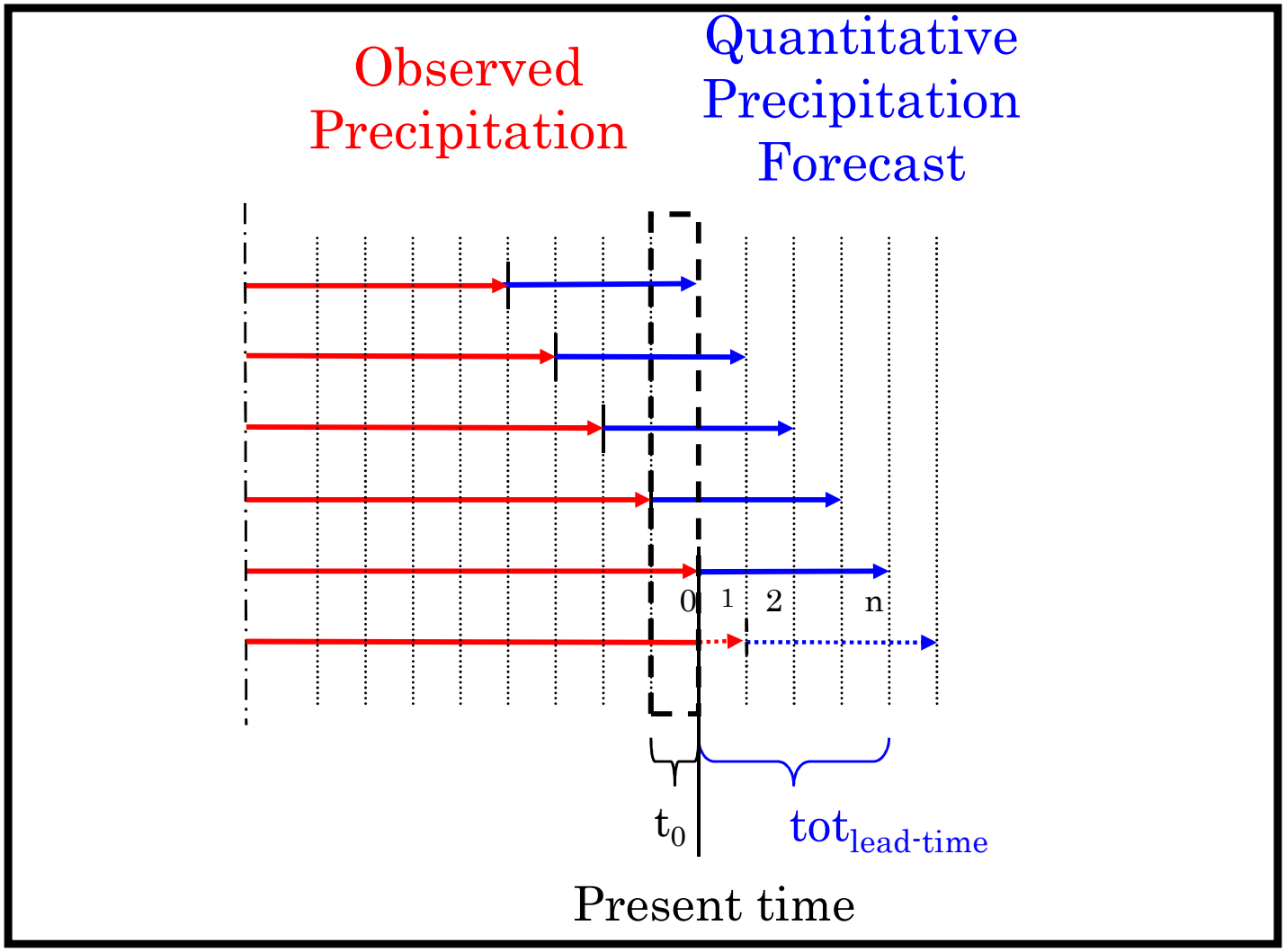
- Flood Warning Support System (FLOWSS)

  Goal: Emit flood warning to perform evacuation timely

Overview of DRESS System



Error evaluation window



Intensity **Extension**

$$Total\,ratio = 0.5 \times \left\{ \frac{High\_Intensity_{QPF}}{High\_Intensity_{OBS}} \right\} + 0.5 \times \left\{ \frac{Mean\_Intensity_{QPF}}{Mean\_Intensity_{OBS}} \right\}$$

Integrated error evaluation

Forecast error as function of

1. Location: analysis area defined by buffers

2. Intensity: ratio of maxima and mean

3. Extension: % of covered evaluated zone

Contingency Table for Rain Events

	Too little	**Approx. Correct**	**Too much**
Close	Underestimate	Hit	Overestimate
Far	Missed event	Missed Location	False alarm

Ebert & McBride (2000)

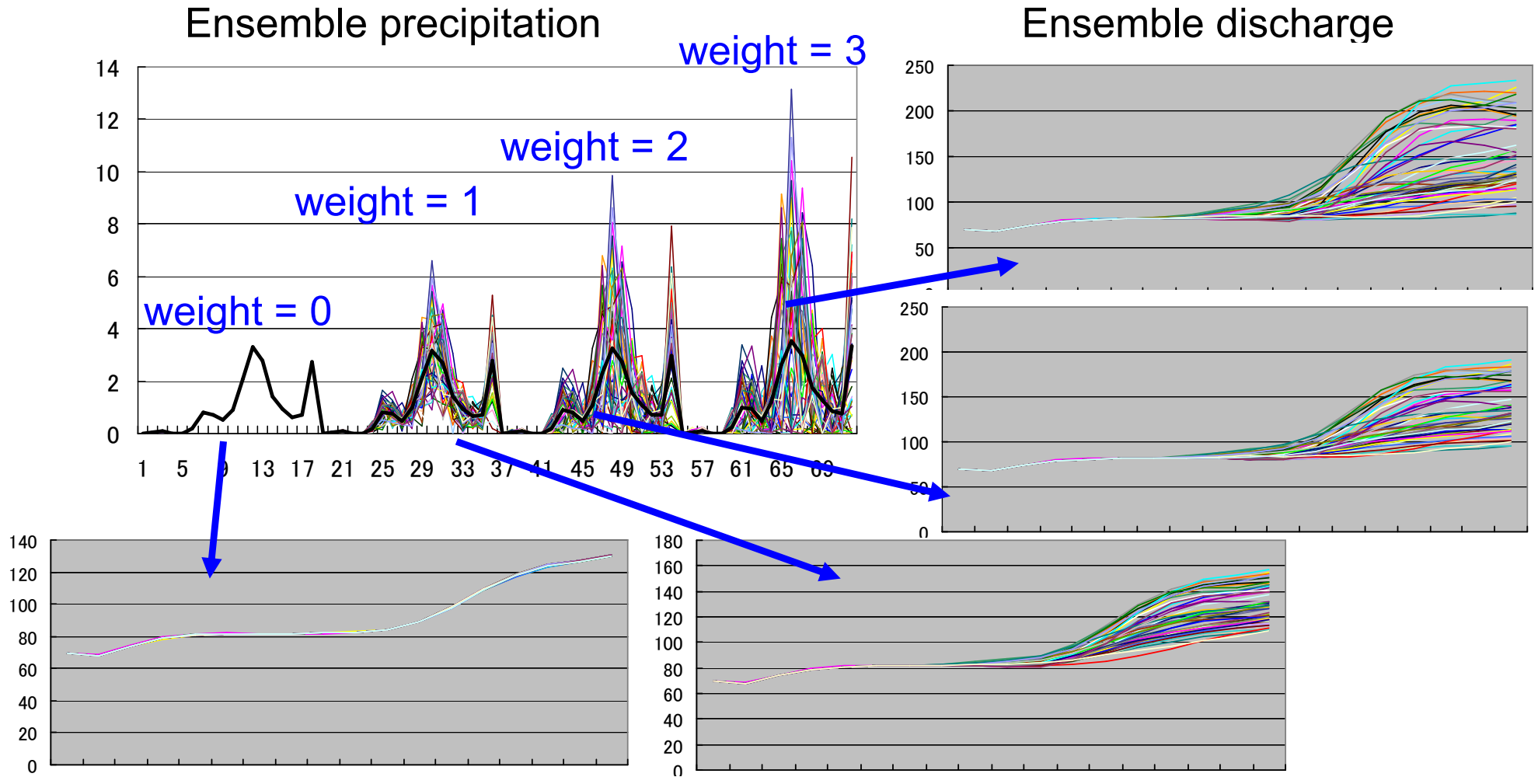
Ensemble member generation of QPF

$$GP(x,y)_k = Max\{QPF(x,y)\times(1+A\varepsilon N(0,1)\times wi_{sub} + B\varepsilon N(0,1)\times wi_{tot}),\ 0\}$$

Saavedra, Koike et al., 2010

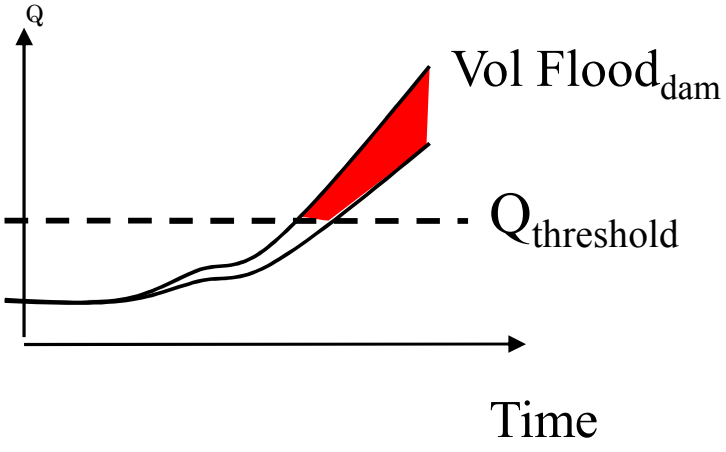
N(0,1) : Gaussian normal distribution

wi_{sub} : weight per sub basin; **wi_{tot}** : weight per sub basin **A, B** : preference

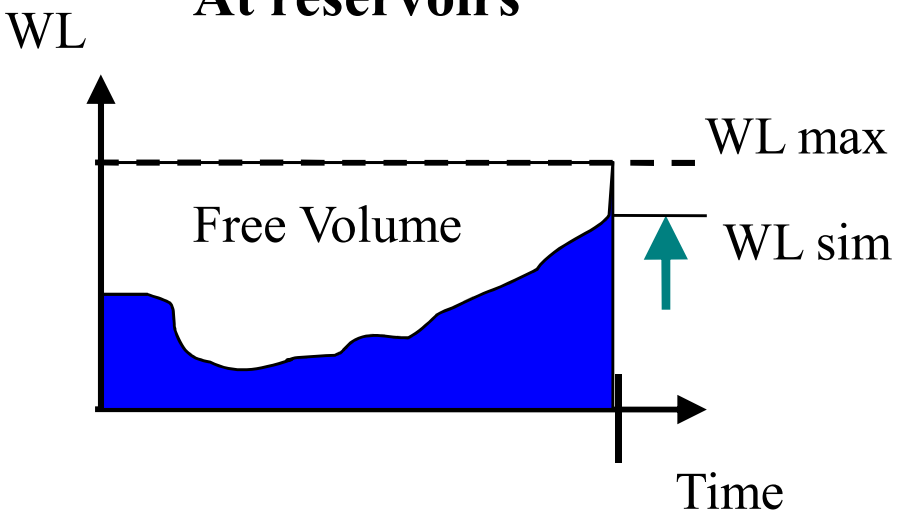


Combined Objective Function

At Control Point



At reservoirs



Saavedra, Koike et al., 2009

$$\sum Vol\_free\_dams = \sum Vol\_\max\_dam - Vol\_sim$$

$$Minimize \quad \{Z = weight\_1 * Vol\_flood + weight\_2 * \sum Vol\_free\_dams\}$$

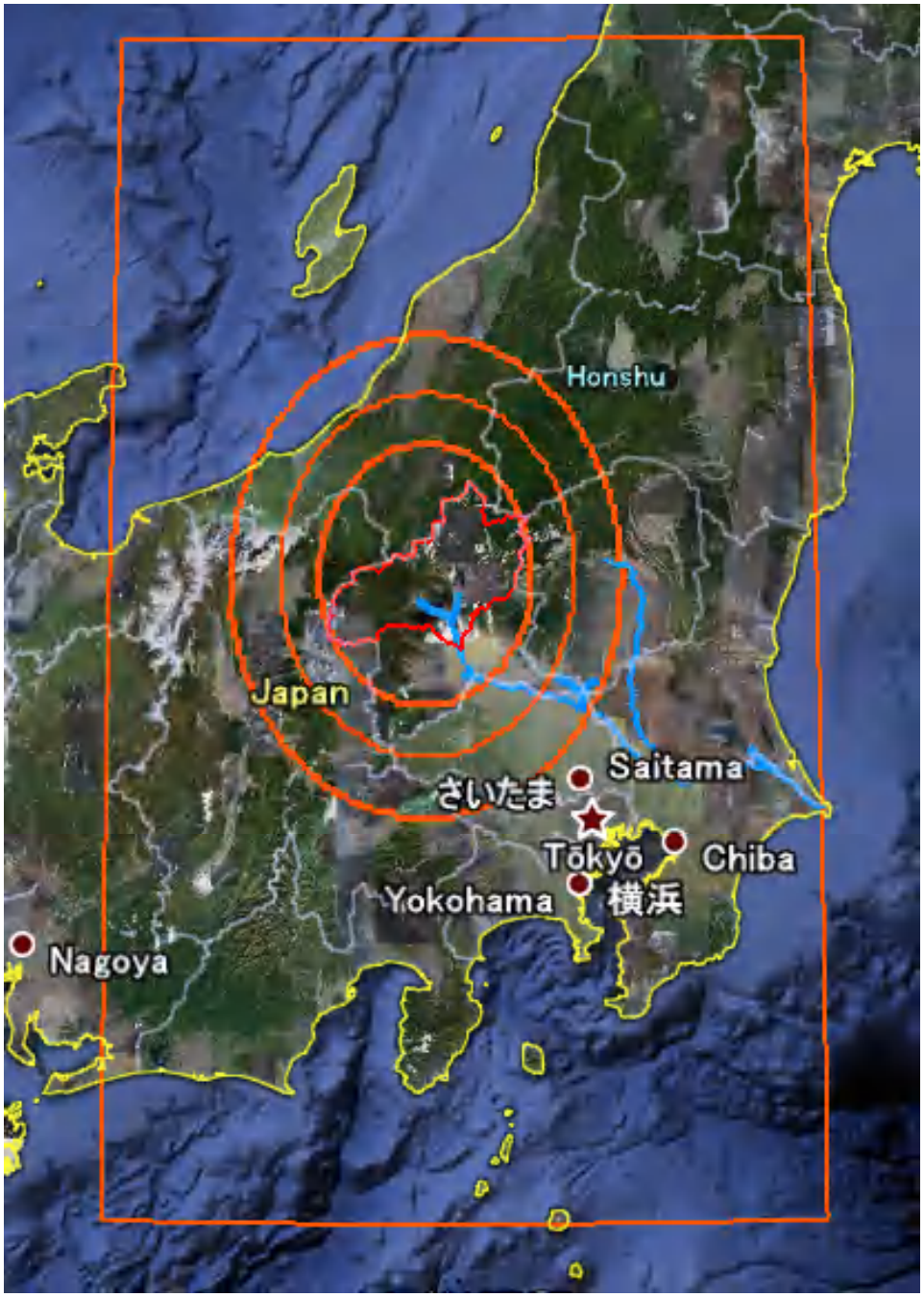
Upper bound: $\mu + \sigma$

$Opt\_var_{dam} = release_{dam}$

Initial guess: μ

Lower bound: $\mu - \sigma$

Upper Tone Reservoir System

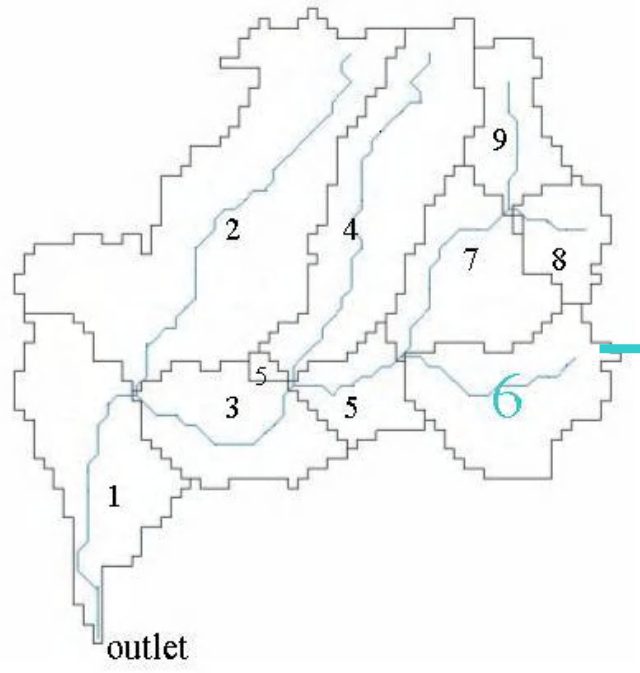


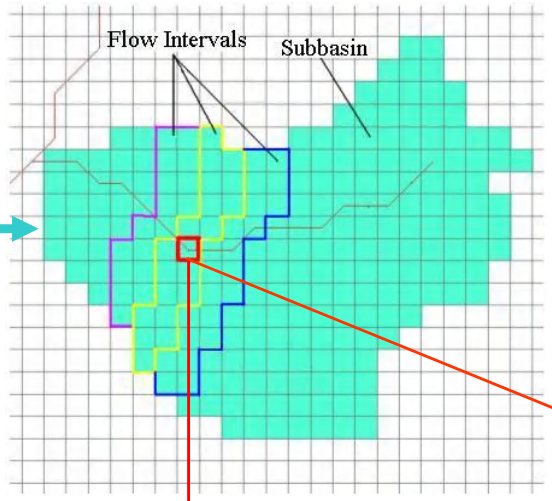
1. Fujiwara (12%)
2. Aimata (3%)
3. Sonohara (15%)
4. Yamba (21%)

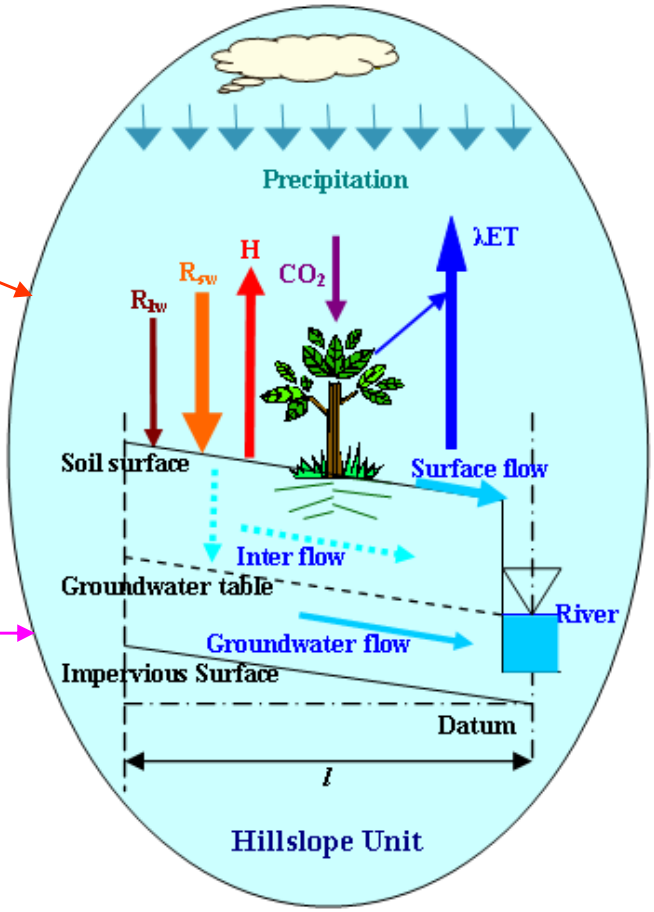
The reservoir system comprises 3304 km^2

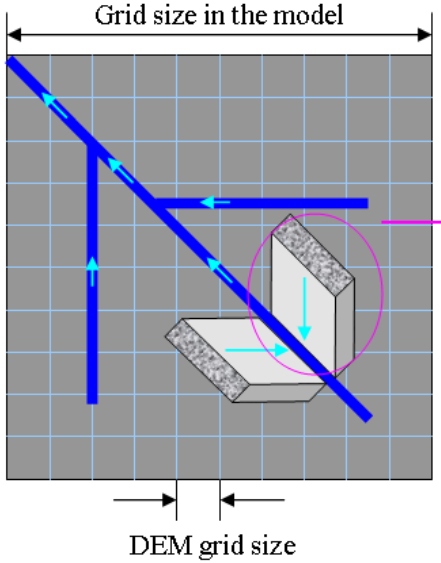
WEB-DHM

(Water and Energy Budget-based Distributed Hydrological Model)

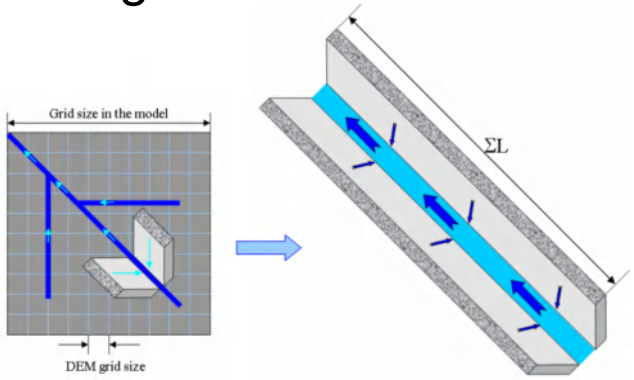






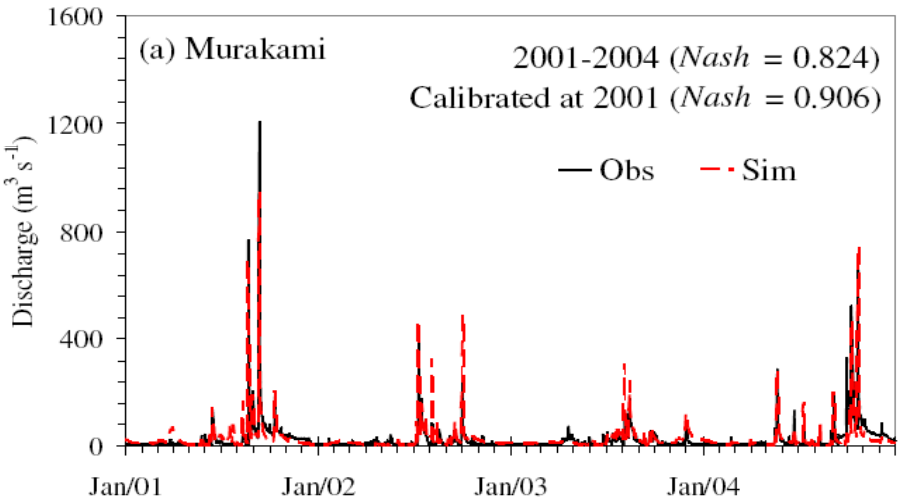


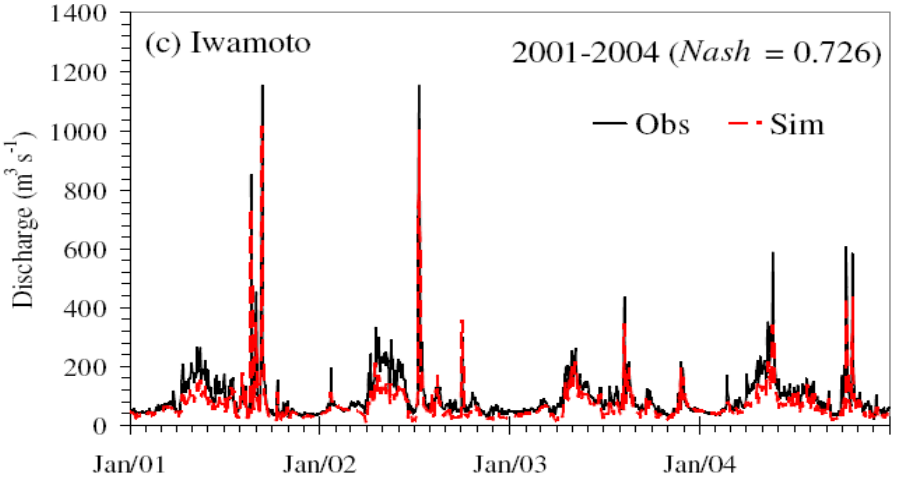
Subgrid Parameterization

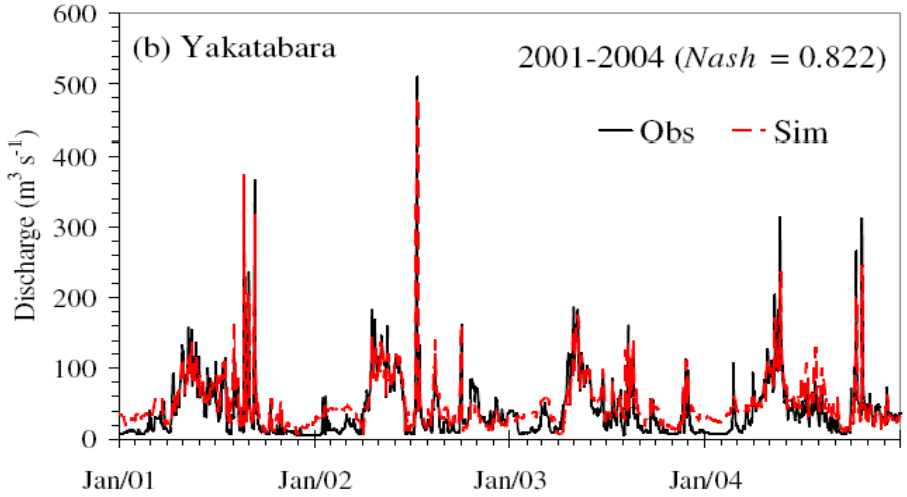


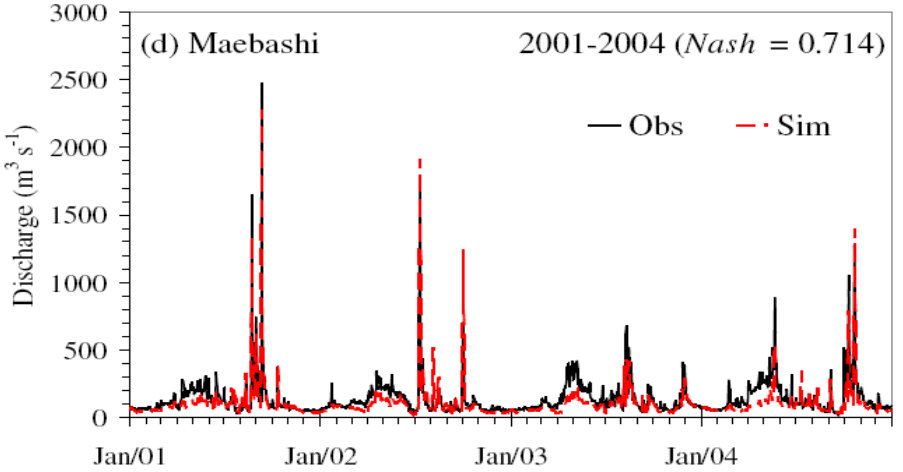
Wang, Koike et al., 2009

Hydrographs (2001-2004)





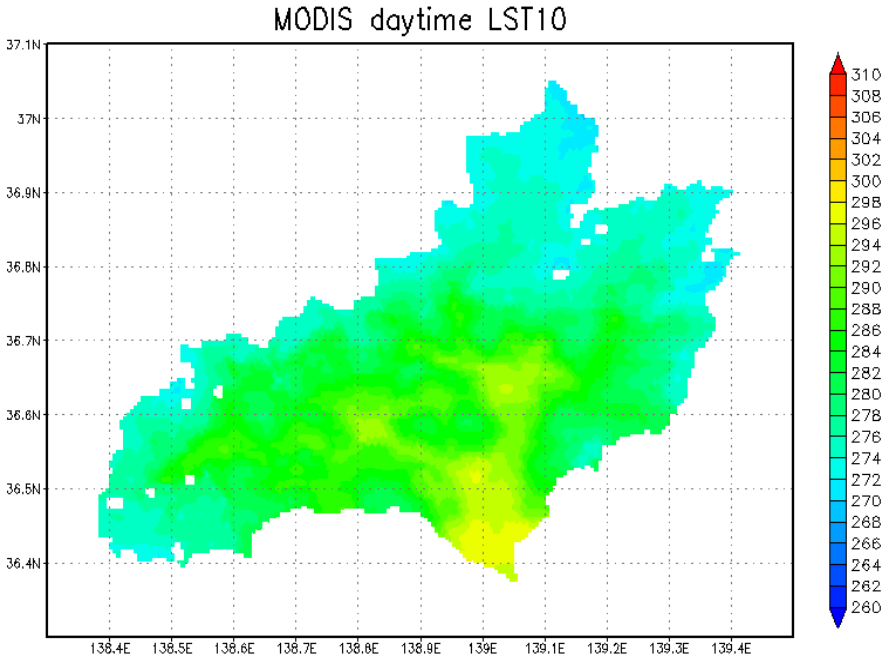




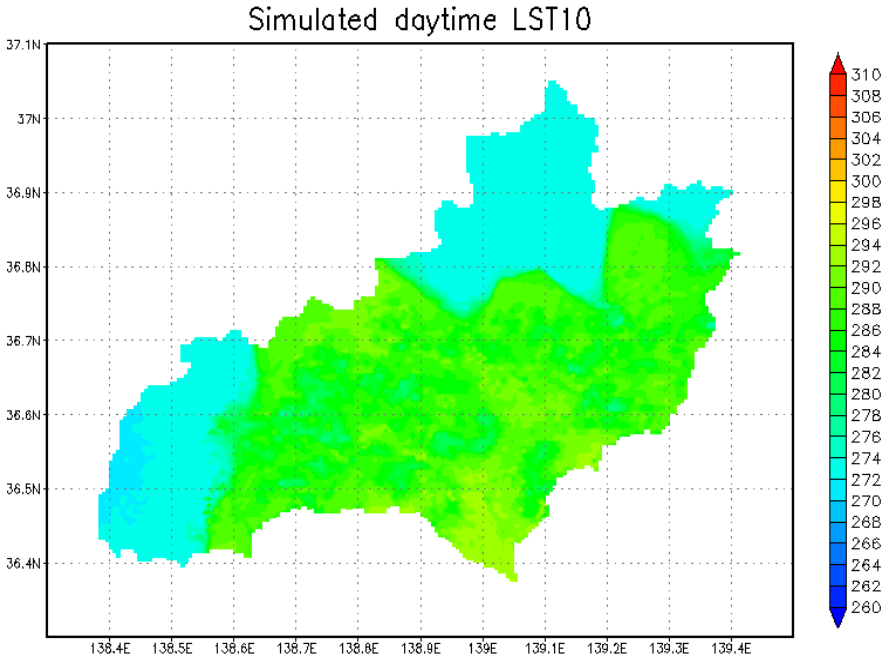
Wang, Koike et al., 2009

Land Surface Temperature validation

Satellite Observation



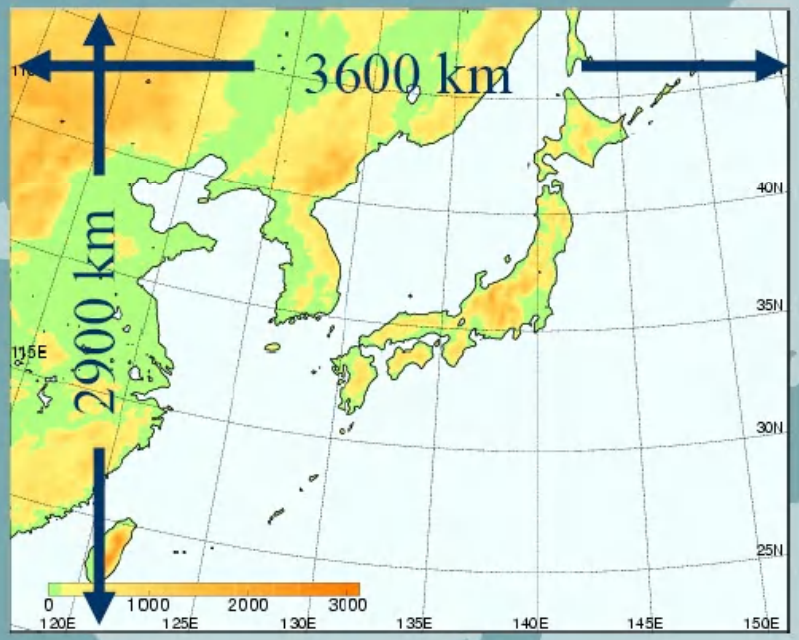
WEB-DHM simulation



10:30 March 13, 2001 (JST)

Wang, Koike et al., 2009

Meso scale model (MSM) at JMA



Computational domain

Use a non-hydrostatic model (JMANHM) operationally.

Until Feb. 2006, From Mar. 2006,

Horizontal resolution : 10km → 5km

Forecast 4 times a day → 8times a day

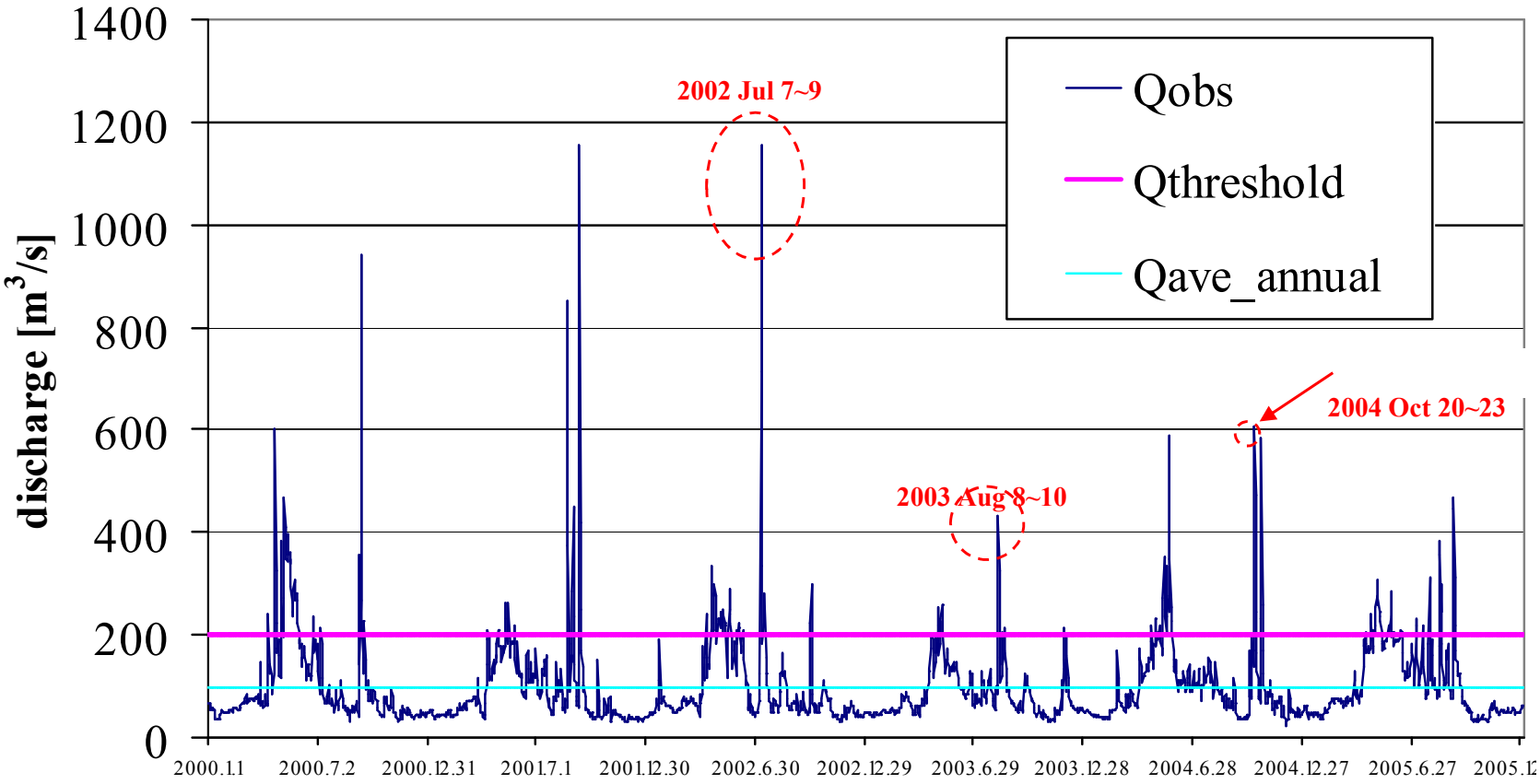
Forecast hour: 18hours → 15 hours

- Dynamics
  - Split explicit scheme(HE-VI)
  - Stable operation with relatively large time step
    : 40 seconds →24 seconds
- Moist process
  - Cloud microphysics(3-ice : cloud ice, snow, graupel)
  - Convective parameterization (Kain-Fritsch)

HARA T., JMA, 2007

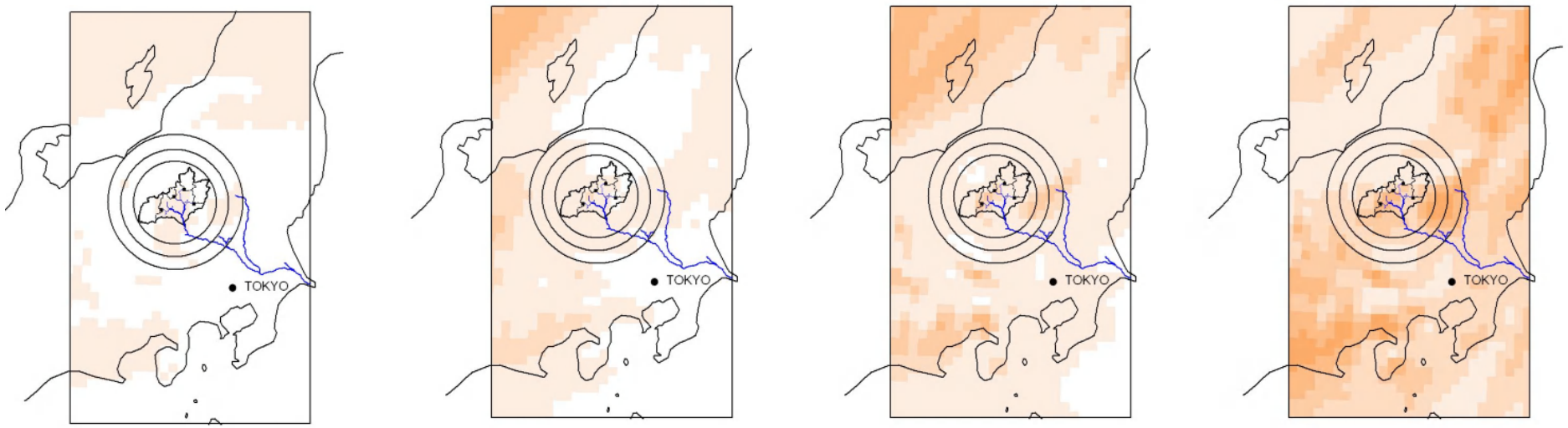
Evaluated events

1) 2002 Jul 7~9
2) 2003 Aug 8~10
3) 2004 Oct 20~23

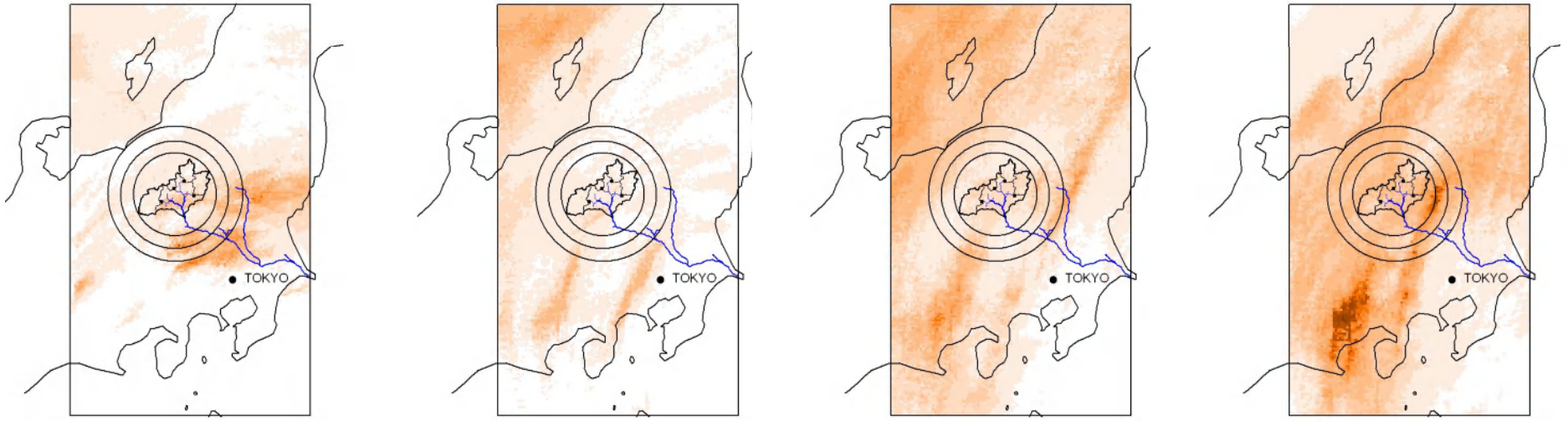


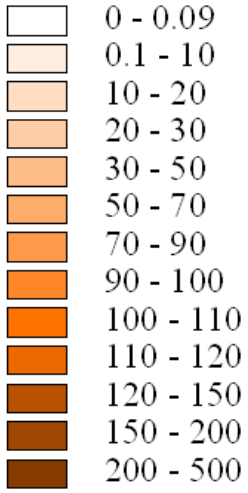
2002.07.09.21z→ 2002.07.10.15z

FORECAST



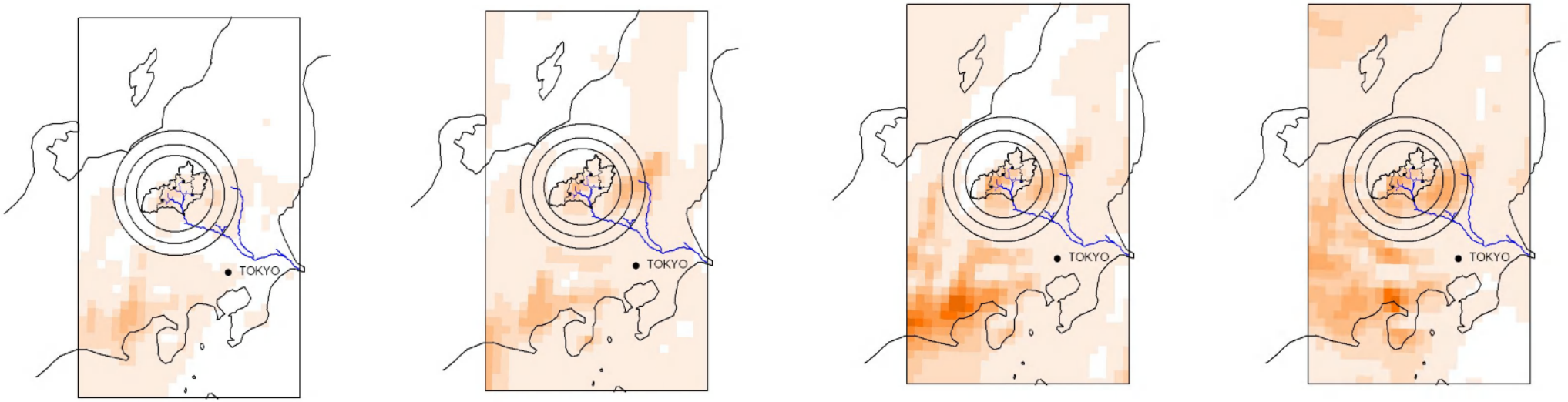
OBS. RADAR



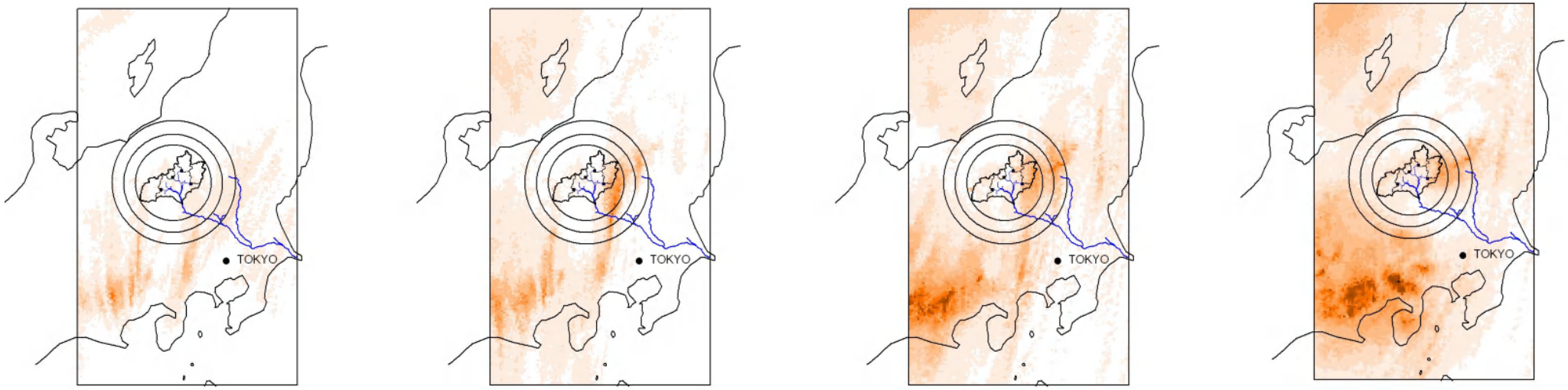


2003.08.08.21z→ 2003.08.09.15z

FORECAST

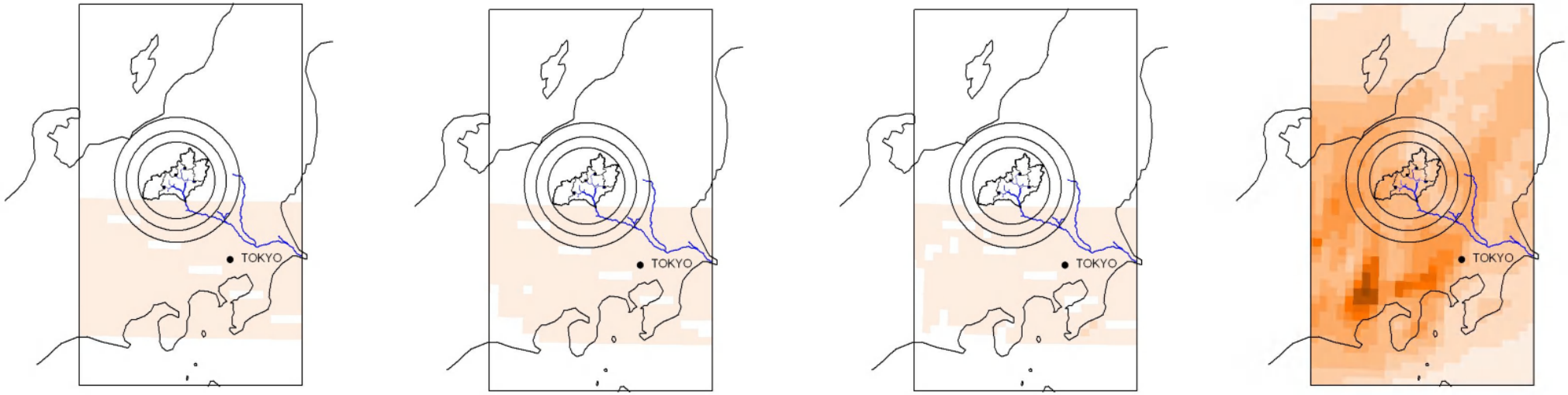


OBS. RADAR

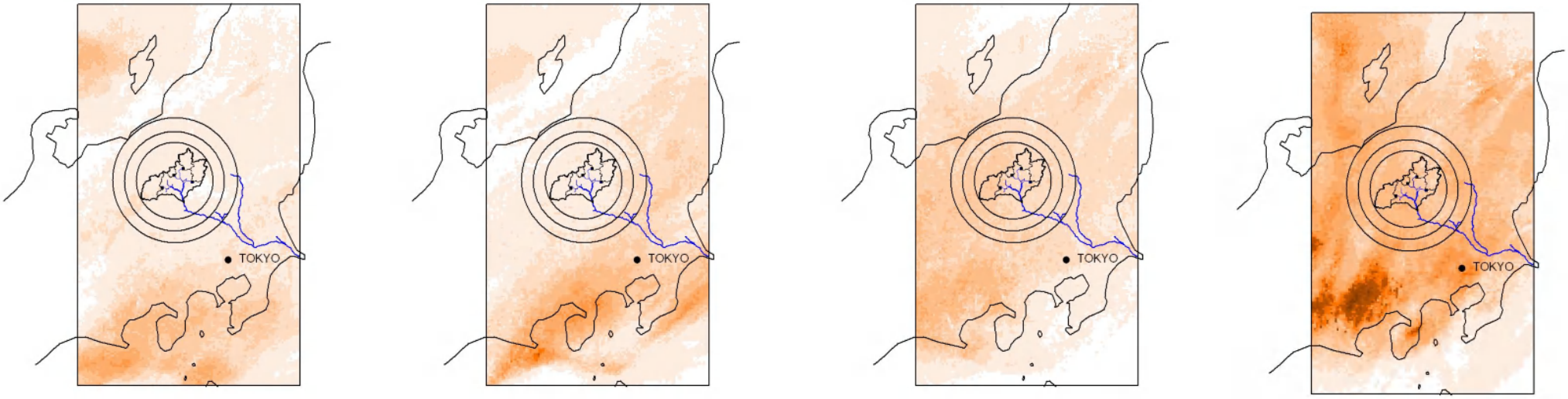


2004.10.20.03z→ 2004.10.20.21z

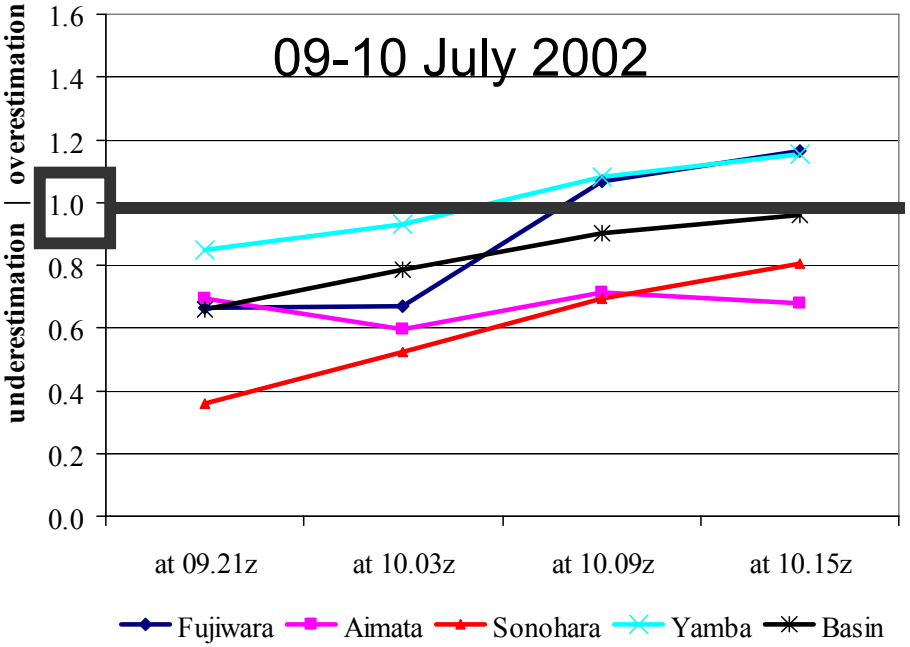
FORECAST(GPV2)

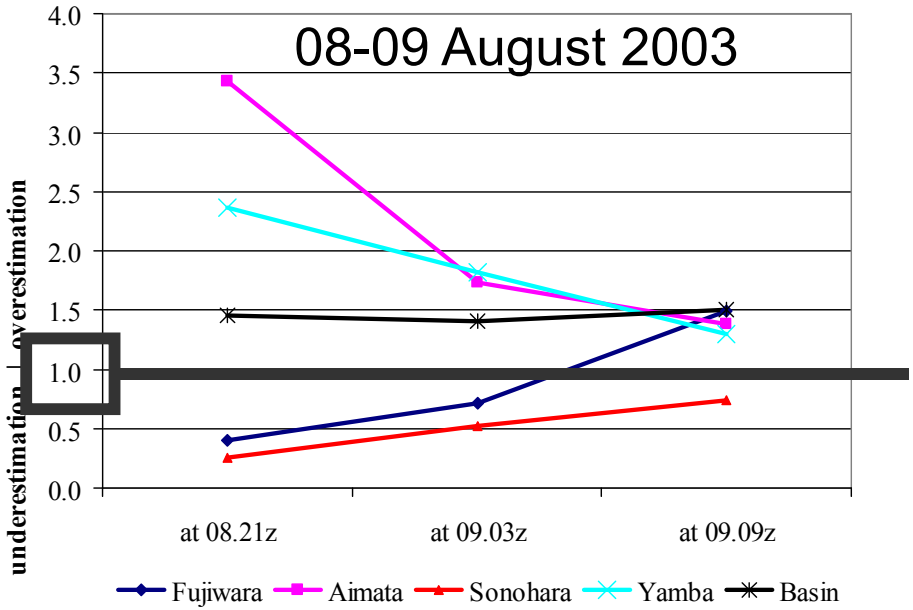


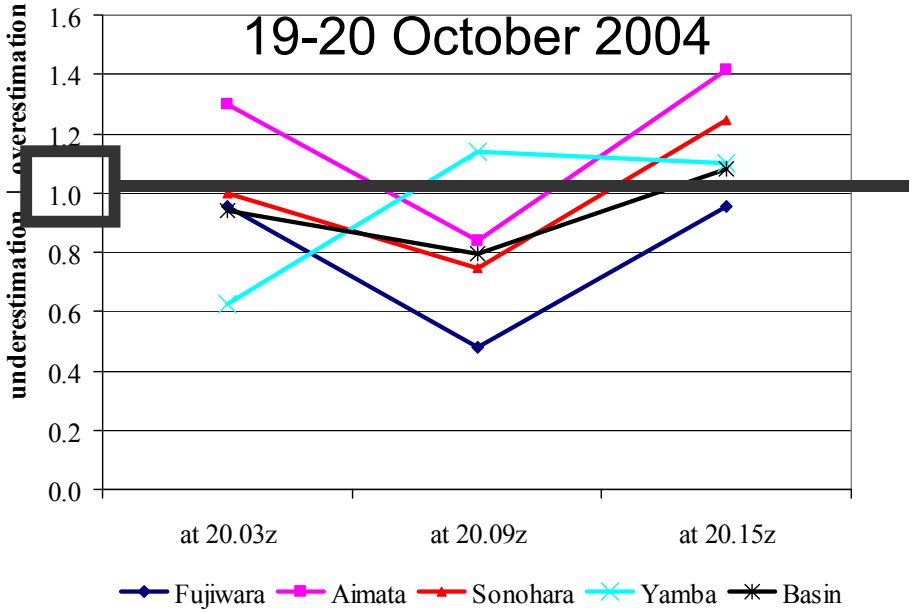
OBS. RADAR



Precipitation ratios QPF over RAD







Weighting Table

Ratio = Intensity_{QPF} / Intensity_{OBS}

(50% of maxima & 50% of mean)

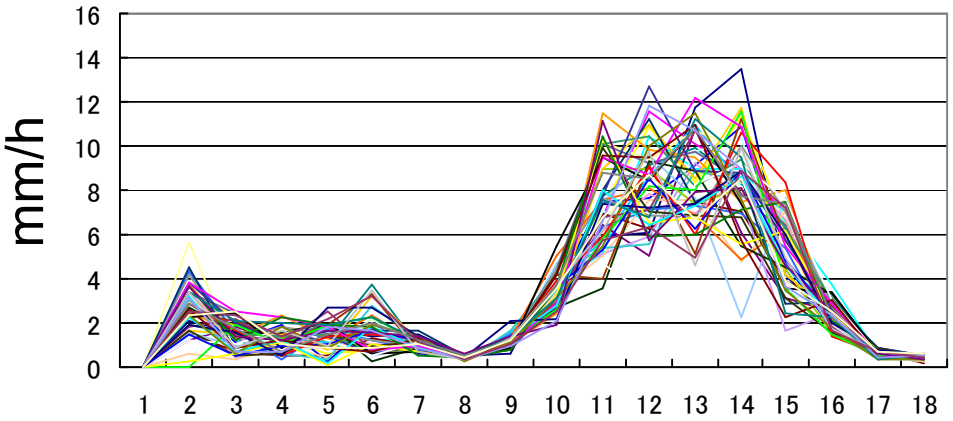
> 1	Overestimation
≈ 1	Very close forecast
< 1	Underestimation

Intensity ratio ranges

	0 - 0.1	0.1 - 0.4	0.4 - 0.7	0.7 - 0.9	0.9 - 1.1	1.1 - 1.3	1.3 - 1.6	1.6 - 1.9	> 2.0
At basin	2.0	1.5	1.0	0.5	**0.0**	0.5	1.0	1.5	2.0
1st buffer	3.0	2.5	2.0	1.5	**1.0**	1.5	2.0	2.5	3.0
2nd buffer	4.0	3.5	3.0	2.5	**2.0**	2.5	3.0	3.5	4.0
3rd buffer	5.0	4.5	4.0	3.5	**3.0**	3.5	4.0	4.5	5.0
All domain	6.0	5.5	5.0	4.5	**4.0**	4.5	5.0	5.5	6.0

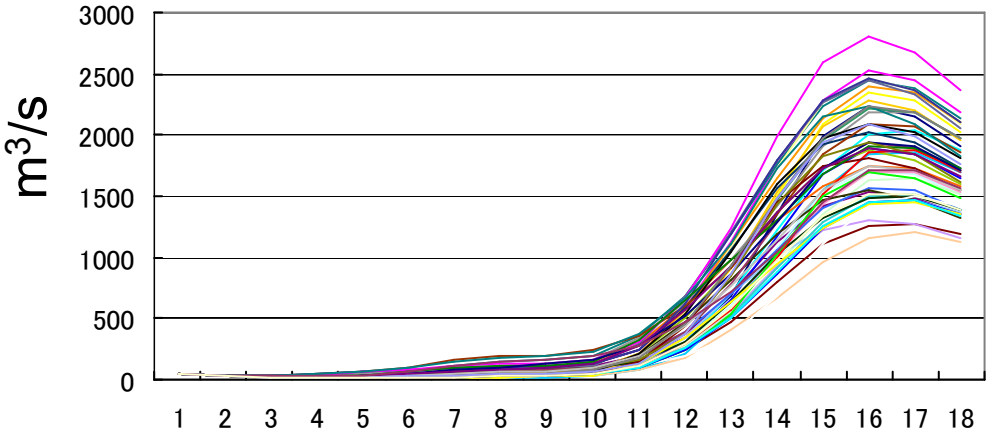
Event 2002 Jul 7~

Ensemble precipitation forecast

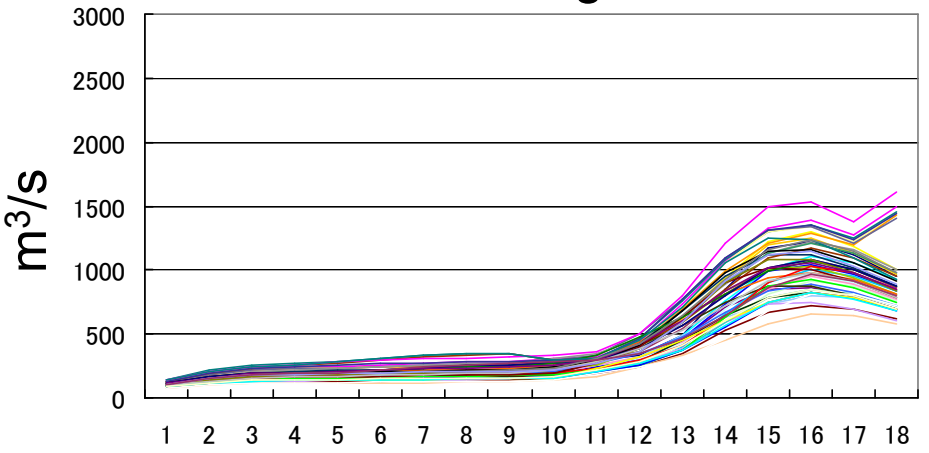


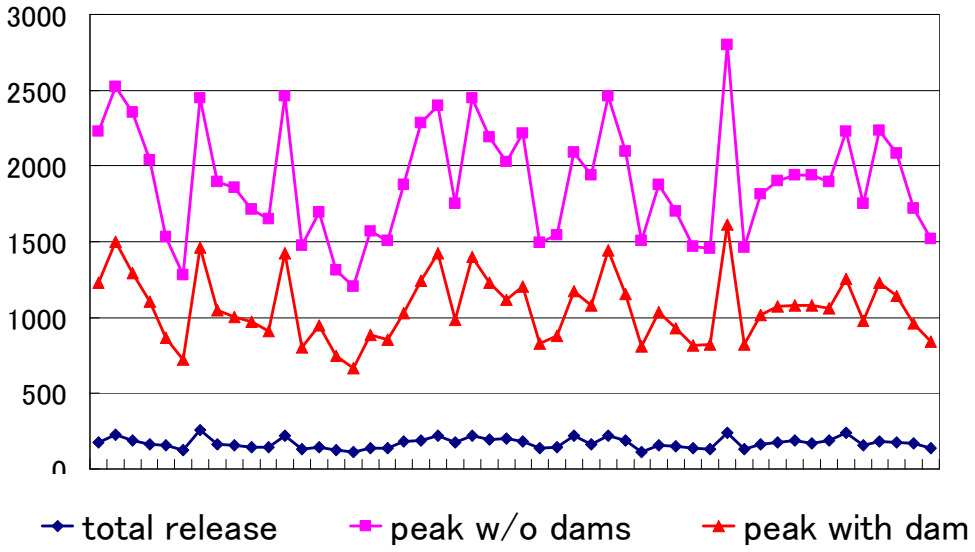
weight1 = 1; weight2 = 0.5; Weight3 = 0.5

Ensemble discharge w/o dams



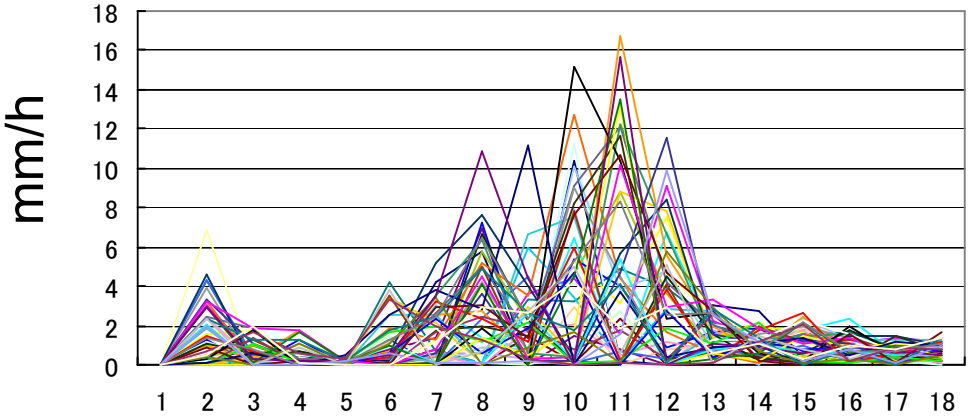
Ensemble discharge with dams



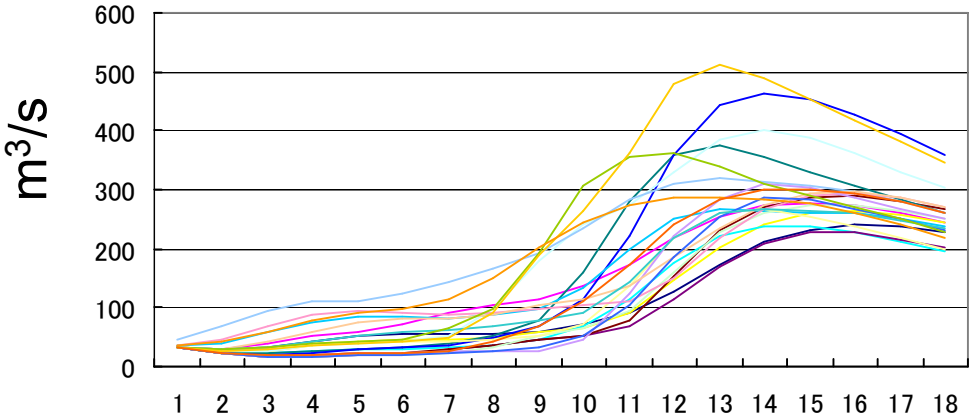


Event 2003 Aug 8~

Ensemble precipitation forecast

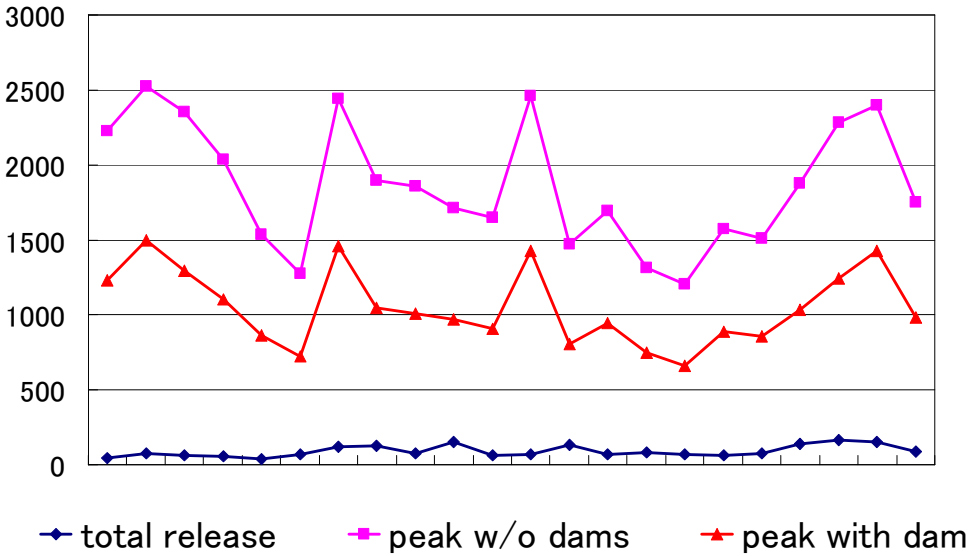


Ensemble discharge w/o dams

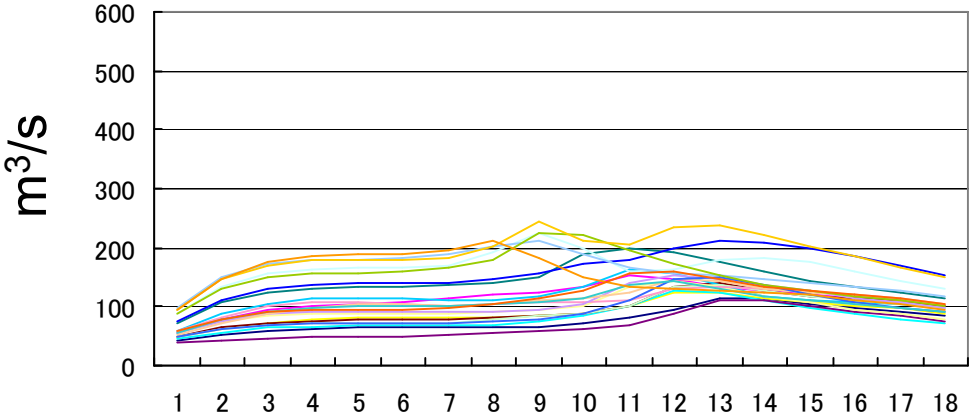


44%→ start system

weight1 = 6; weight2 = 6; Weight3 = 6

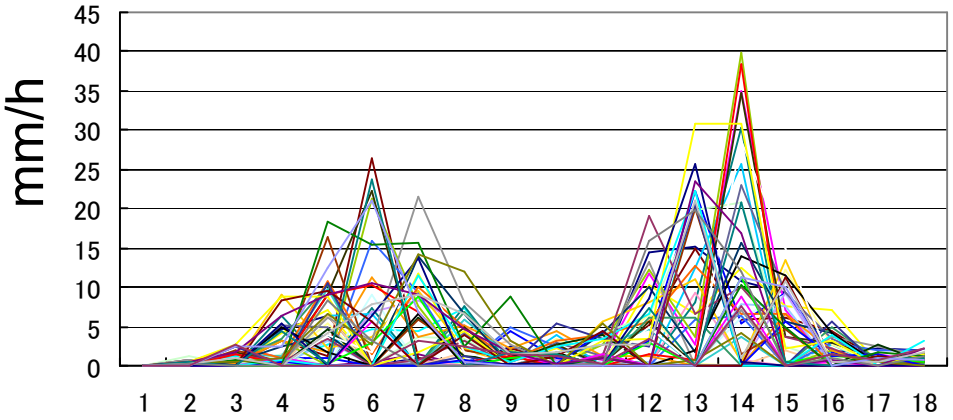


Ensemble discharge with dams



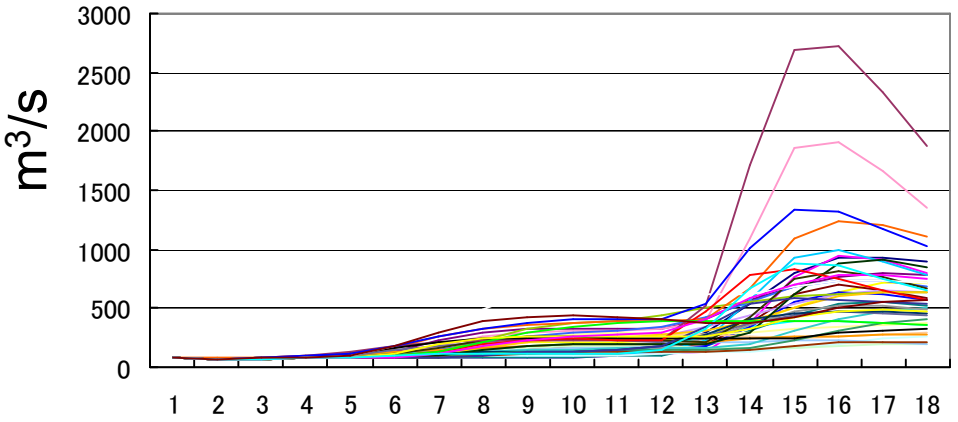
Event 2004 Oct 8~

Ensemble precipitation forecast



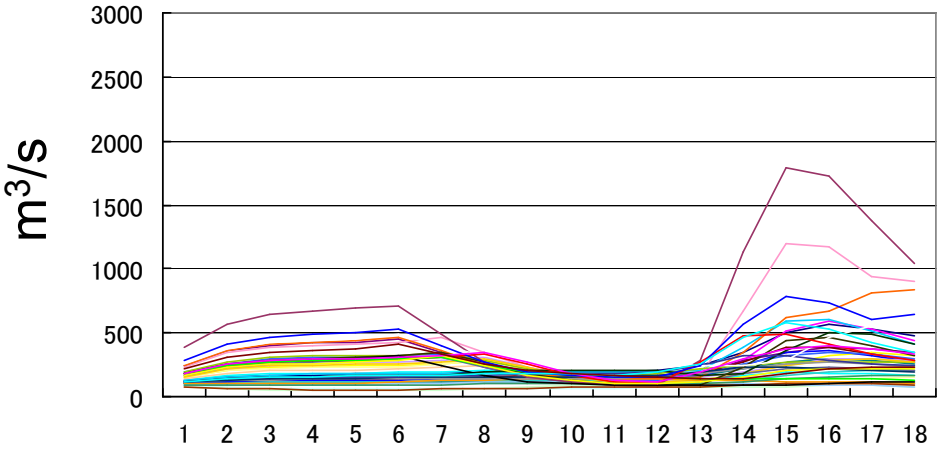
weight1 = 6; weight2 =6; Weight3 = 6

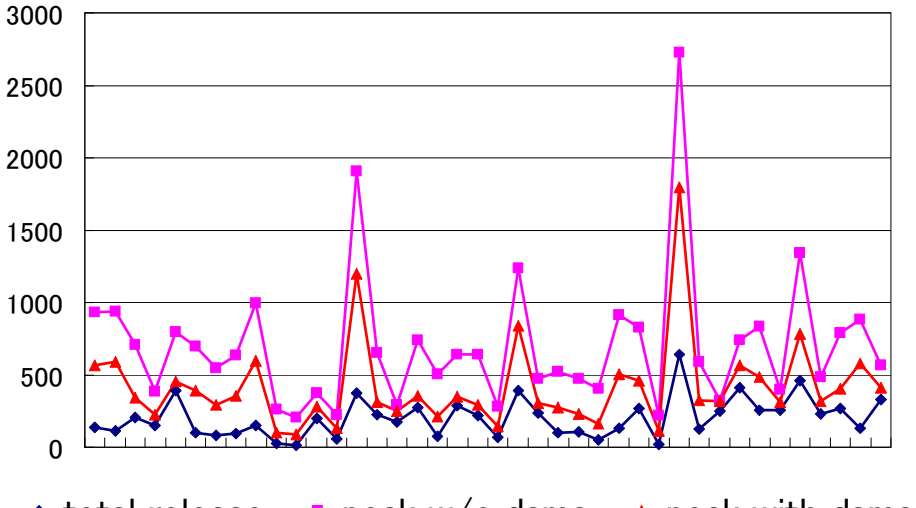
Ensemble discharge w/o dams



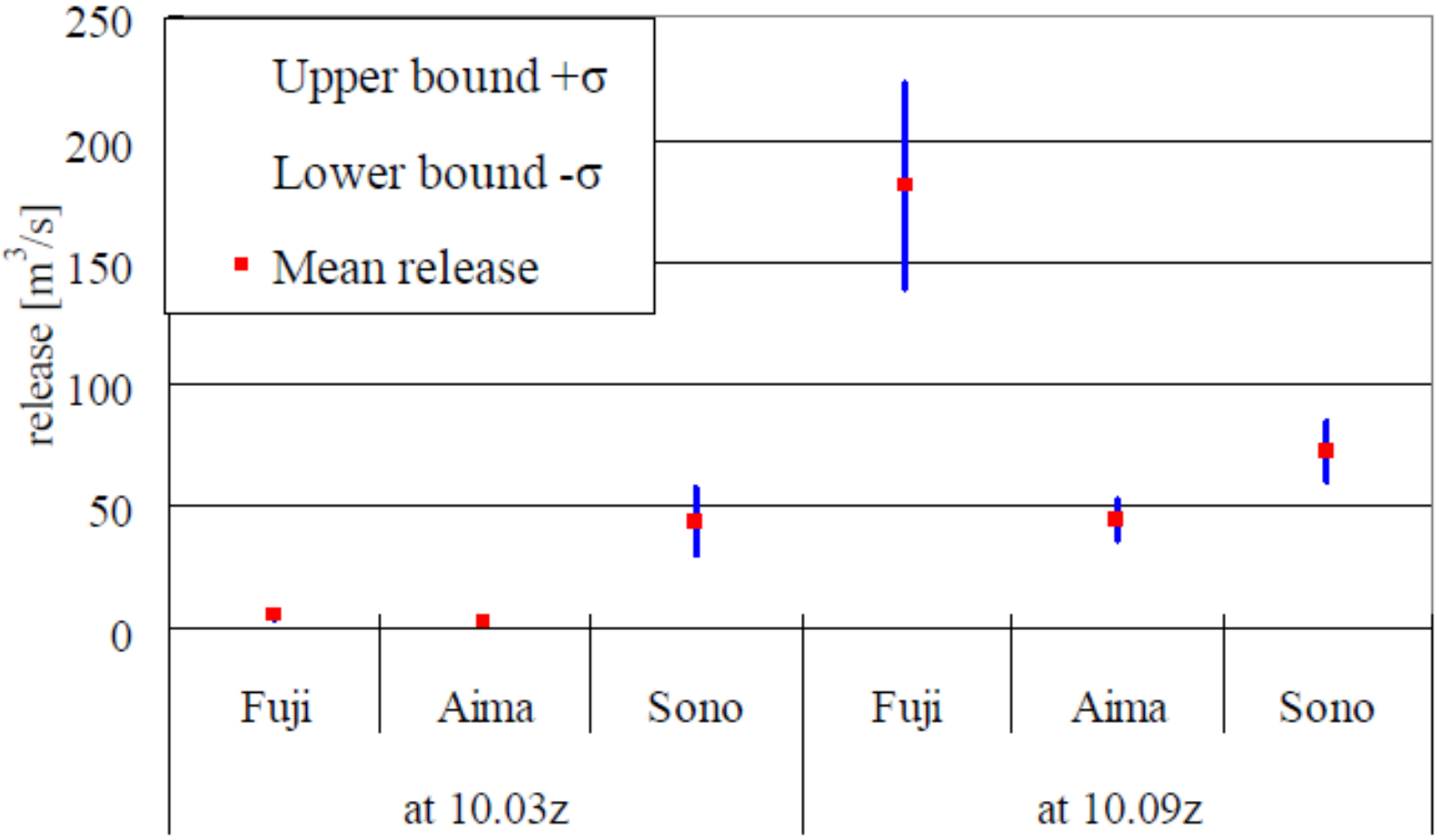
80%→ start system

Ensemble discharge with dams



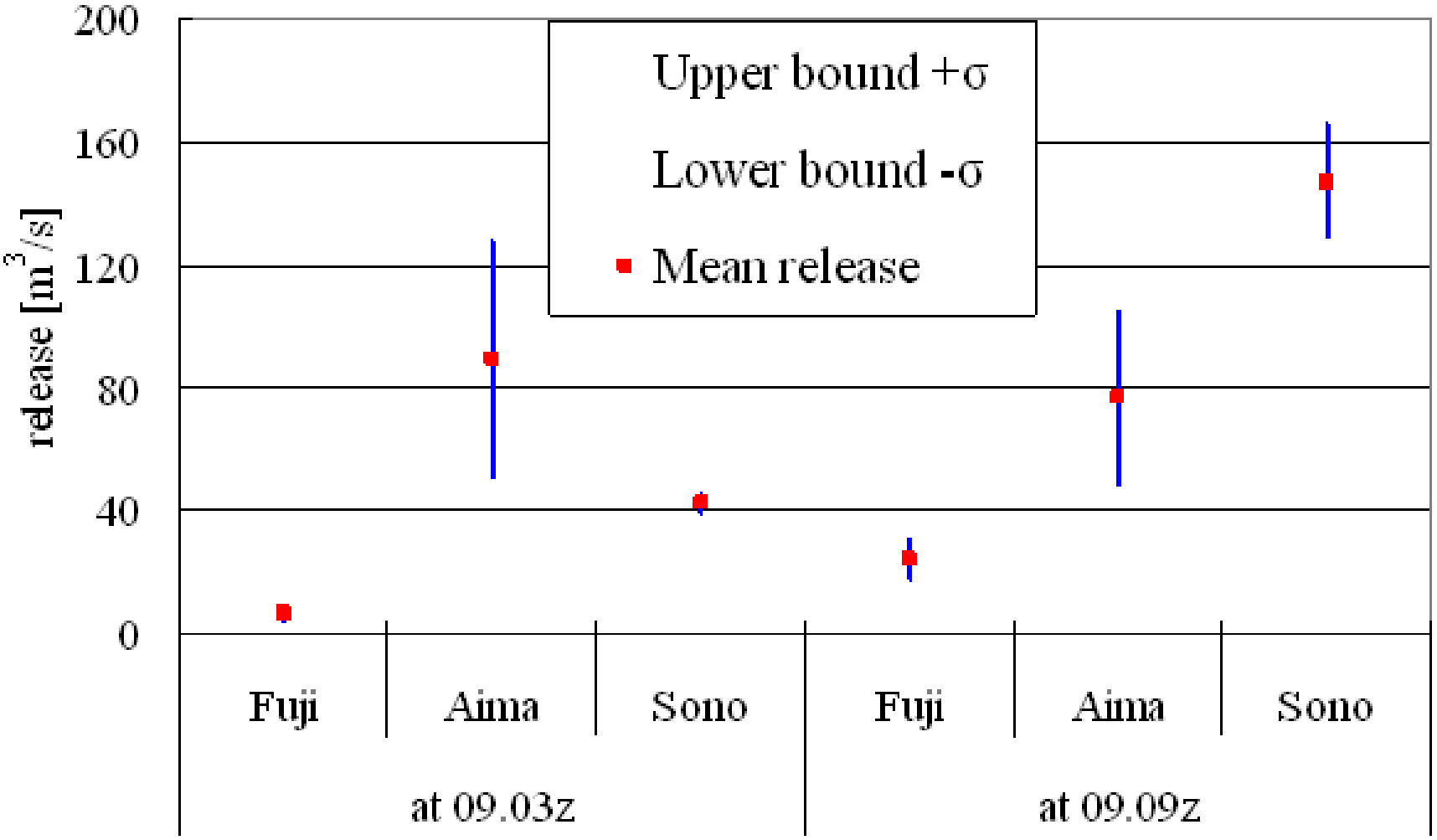


Dam release uncertainties event 9-10 Jul 2002



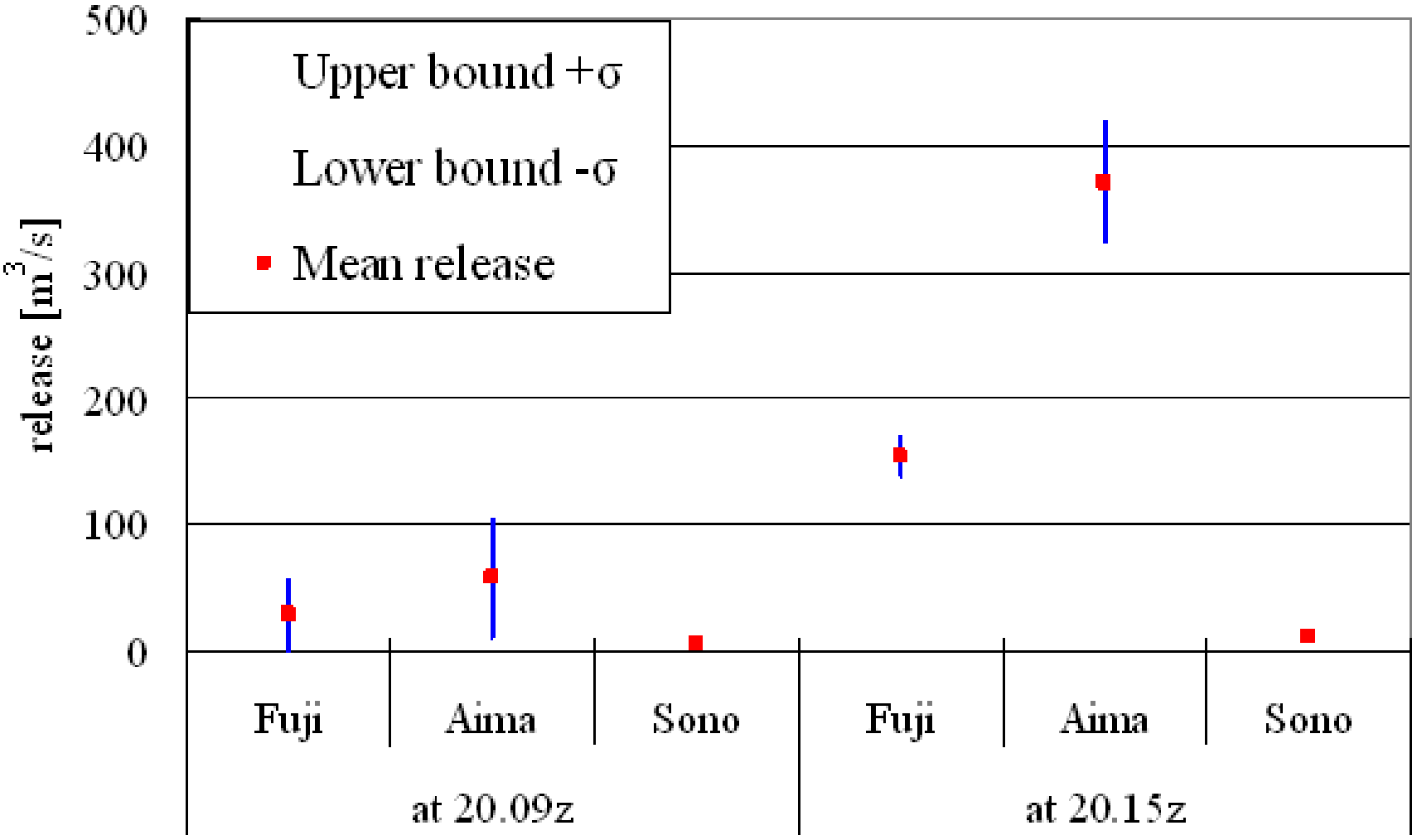
Saavedra, Koike et al., 2010

Dam release uncertainties
event 8-9 Aug 2003



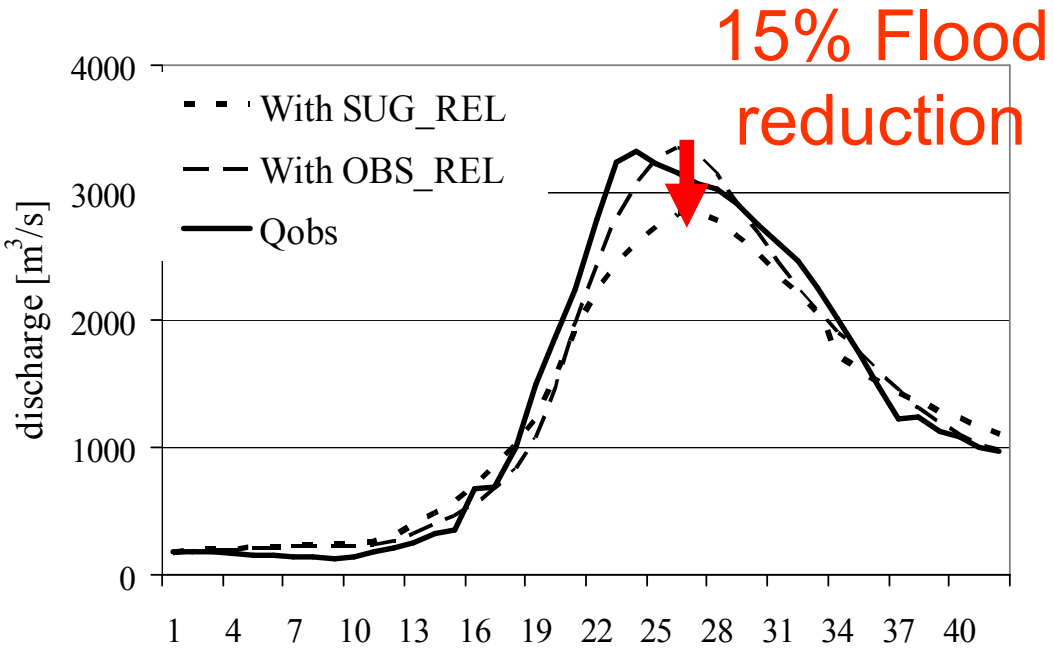
Saavedra, Koike et al., 2010

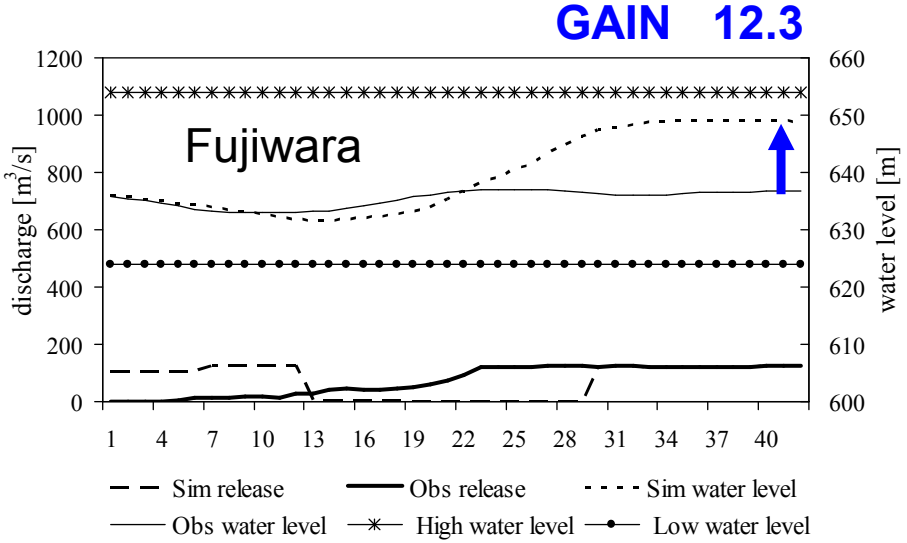
Dam release uncertainties event 19-20 Aug 2004

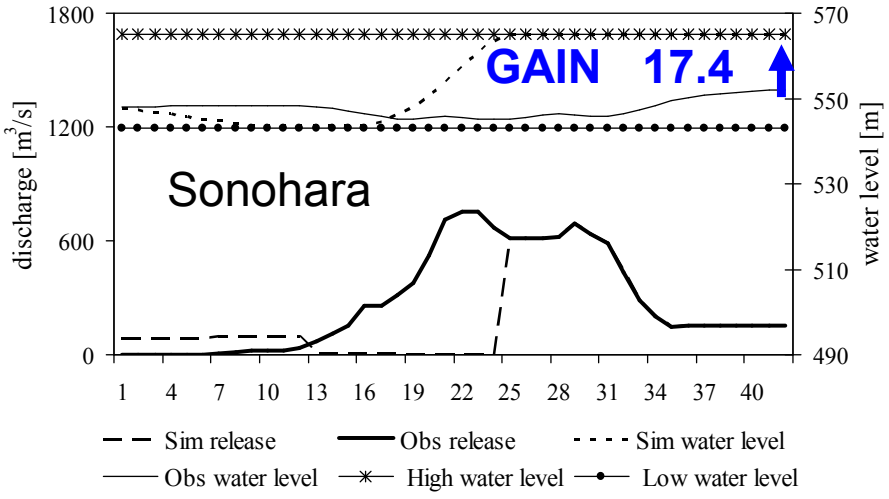


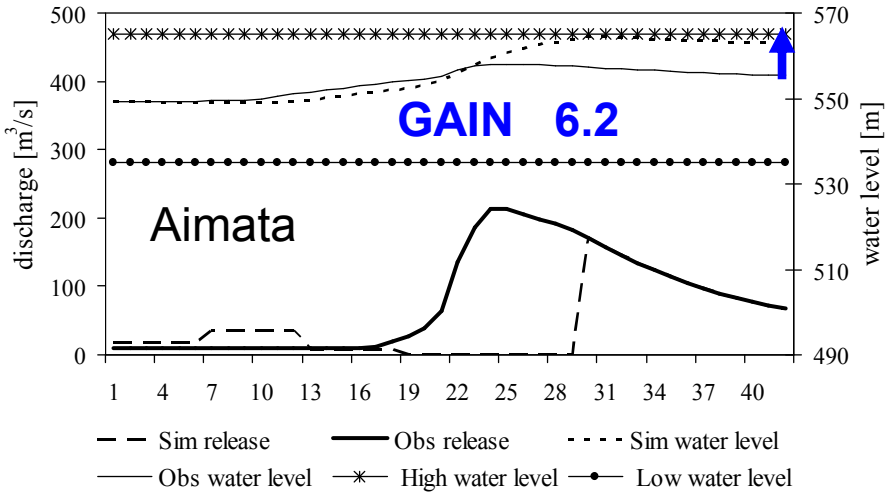
Saavedra, Koike et al., 2010

Results: event 2002 Jul 9~11



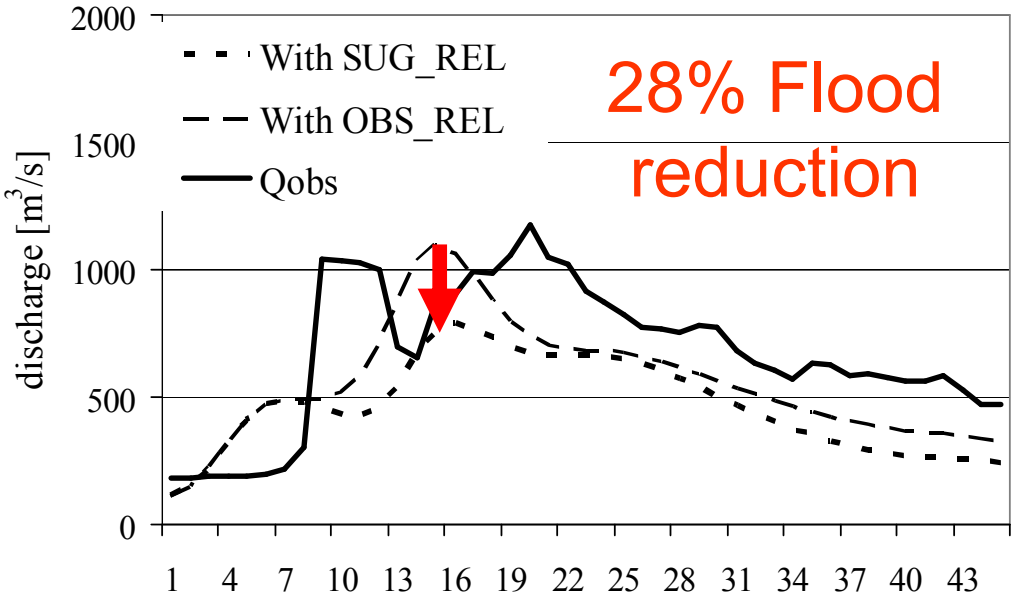


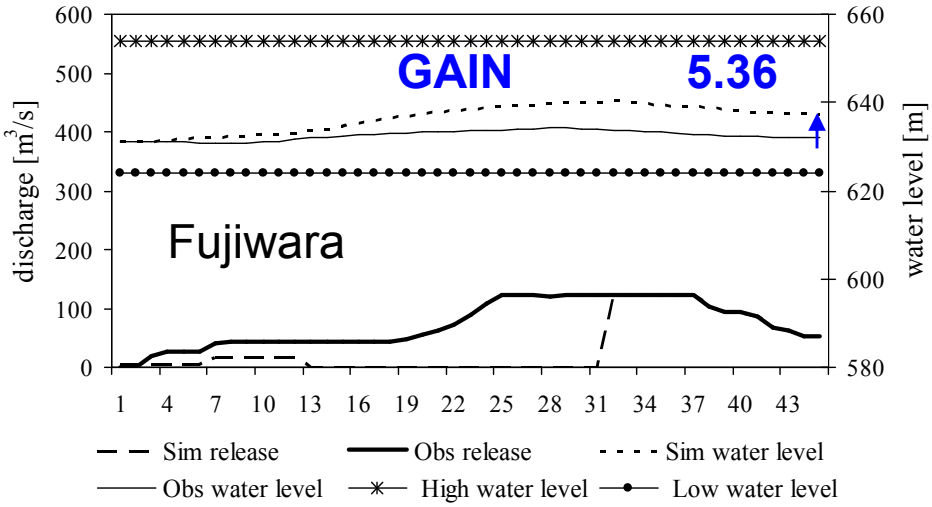


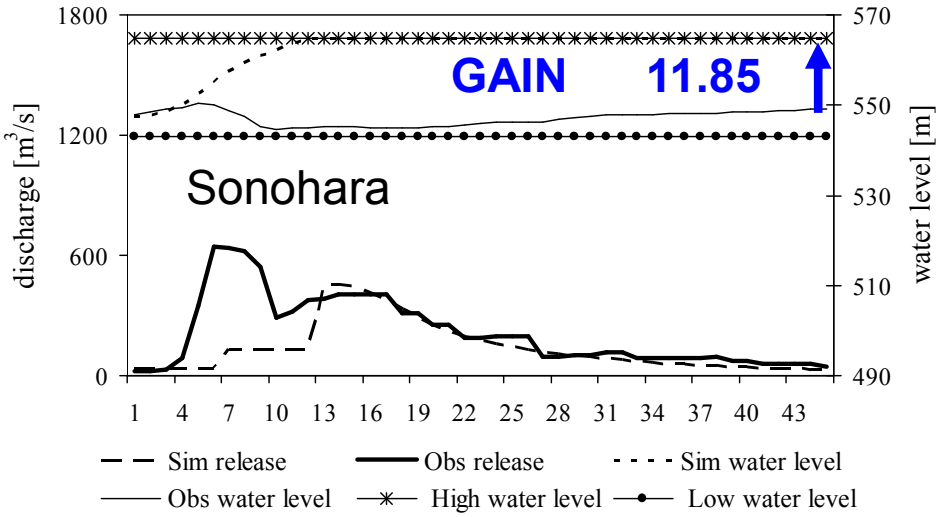


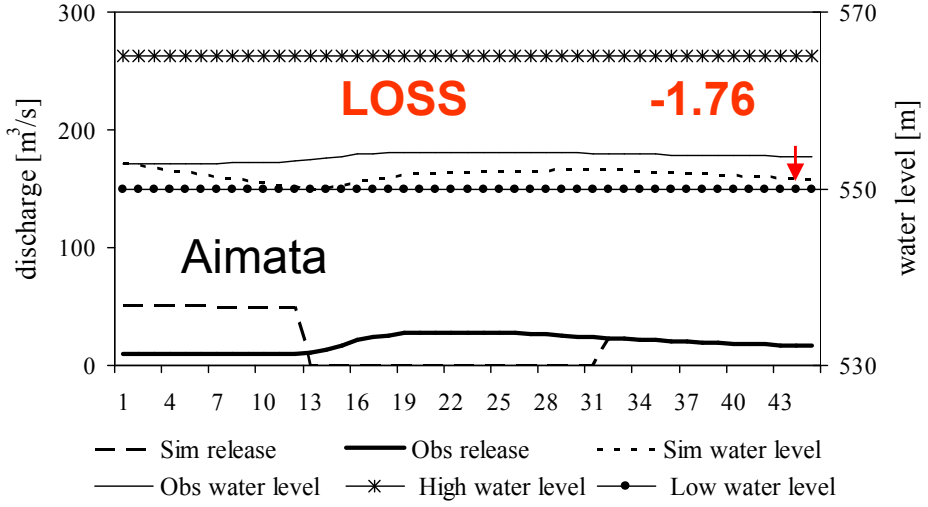
TOTAL GAIN 35.9

Results: event 2003 Aug 8~10



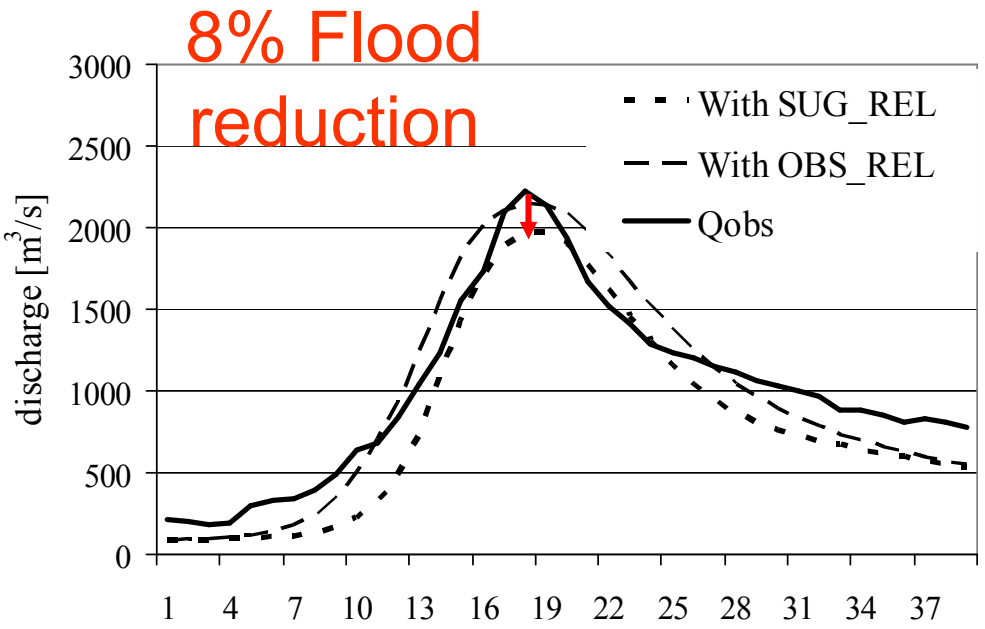


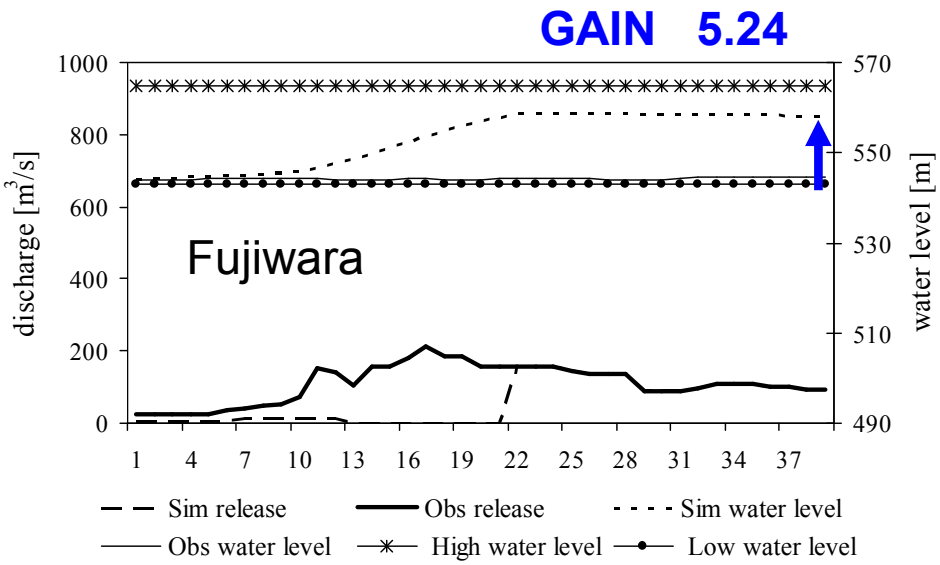


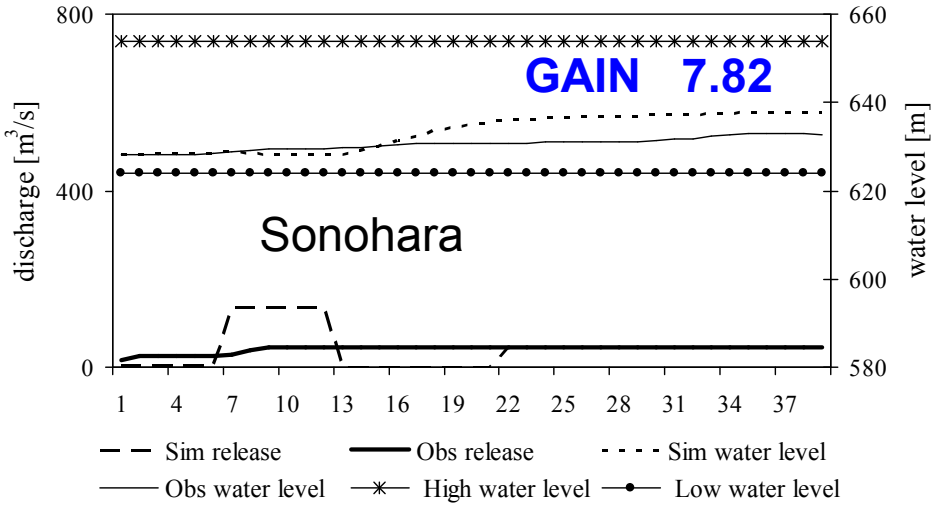


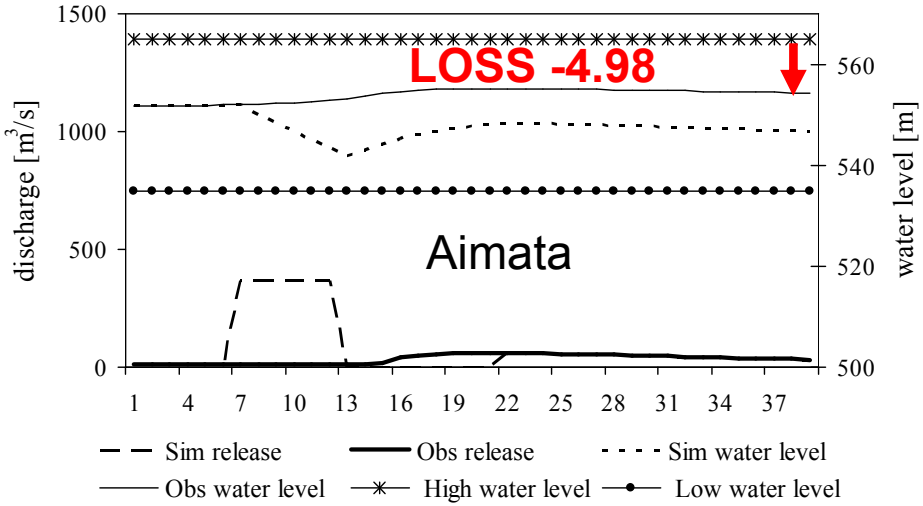
TOTAL GAIN: 15.45 MCM

Results: event 2004 Oct 20~









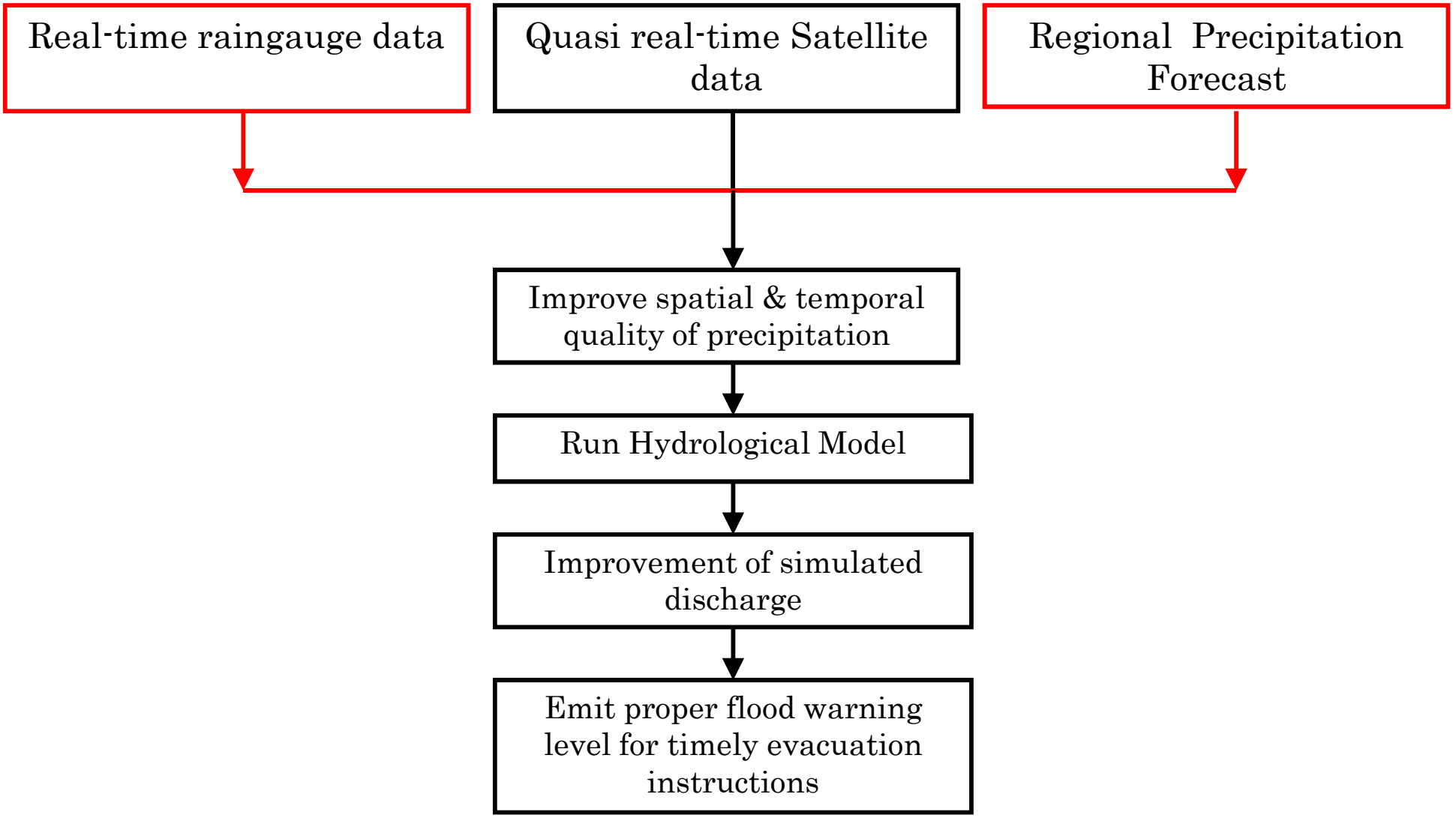
TOTAL GAIN 8.08

Evaluation of the DRESS system's performance

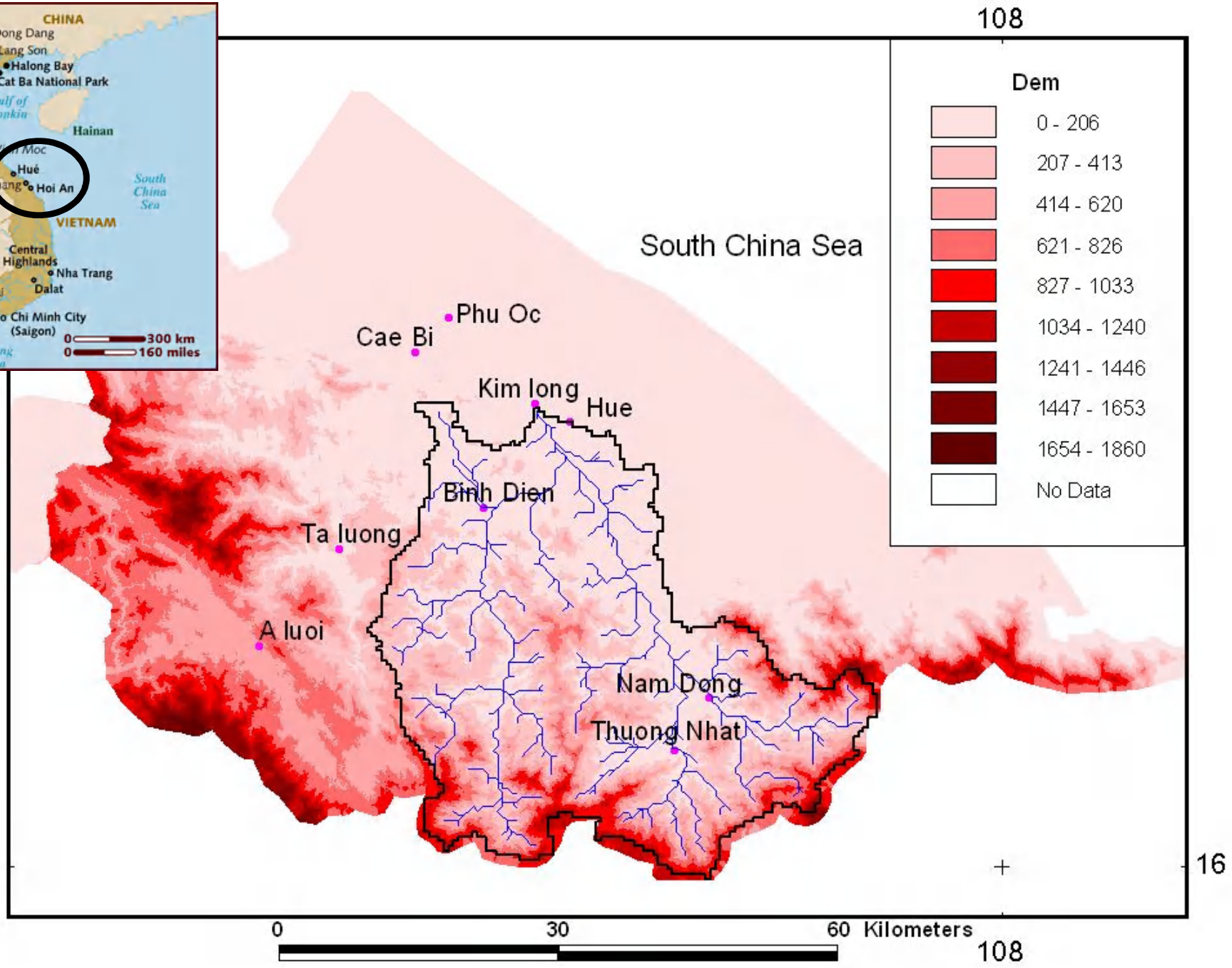
Event	Flood Peak reduction at control point [%]	Gain or Loss at Fujiwara reservoir [MCM]	Gain or Loss at Aimata reservoir [MCM]	Gain or Loss at Sonohara reservoir [MCM]	Total Gain or Loss, reservoirs [MCM]
2002.07	**18.14**	**10.45**	**8.28**	**17.43**	**17.43**
2003.08	**28.03**	**5.36**	**-1.76**	**11.85**	**11.85**
2004.10	**7.6**	**5.24**	**-4.98**	**7.82**	**7.82**

Saavedra, Koike et al., 2010

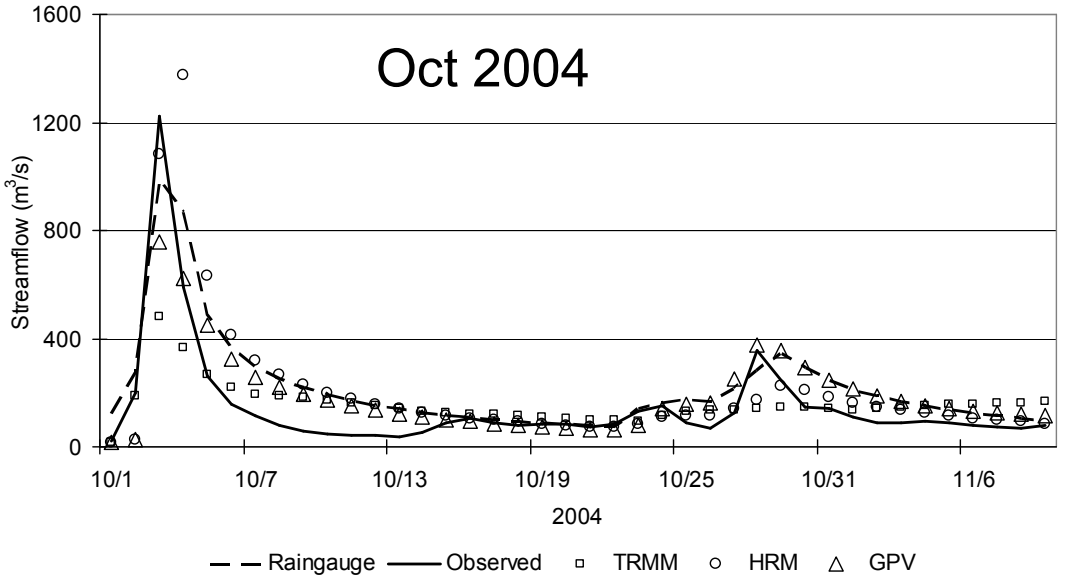
Overview System FLOWSS

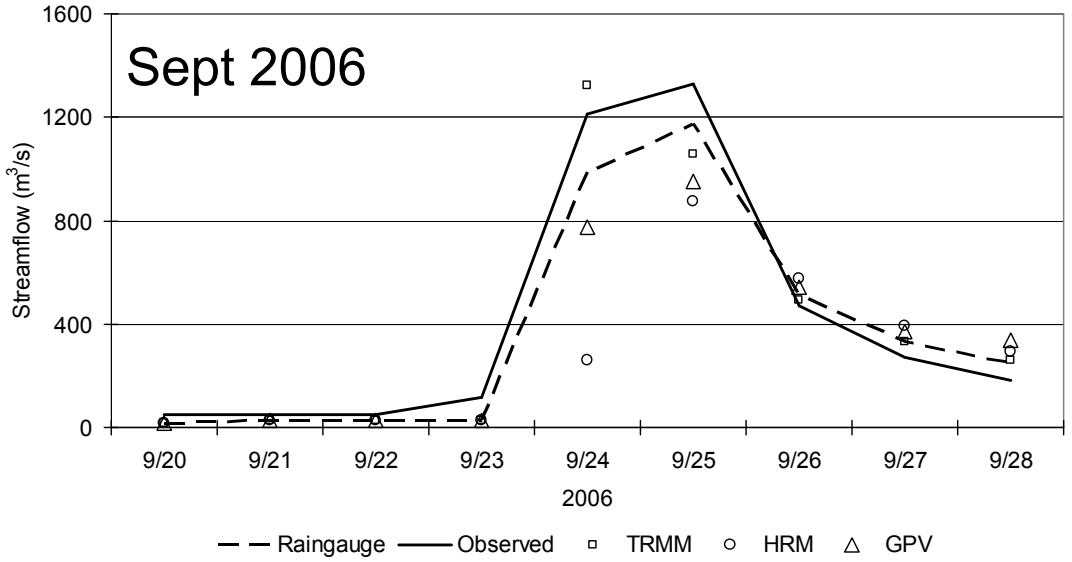


Huong River, Vietnam



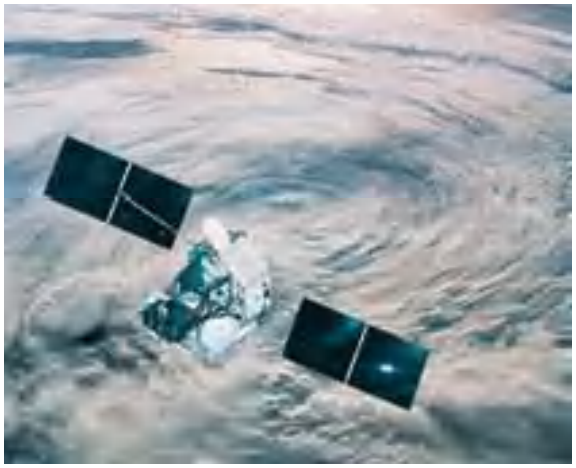
Results of the model

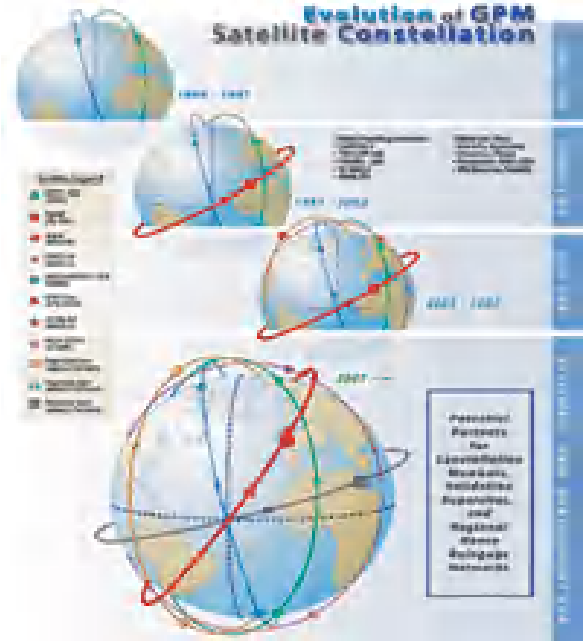


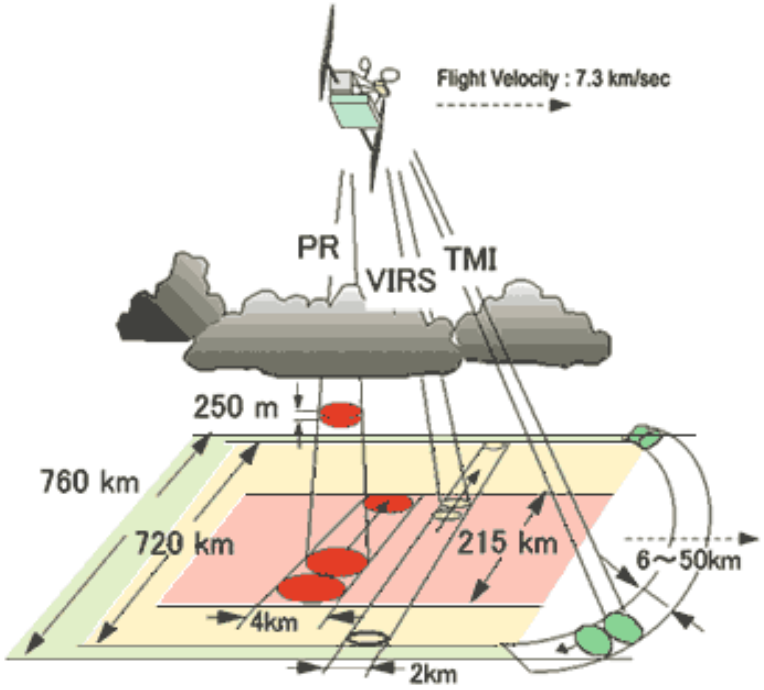


Saavedra, Koike et al., 2009

TRMM sensor



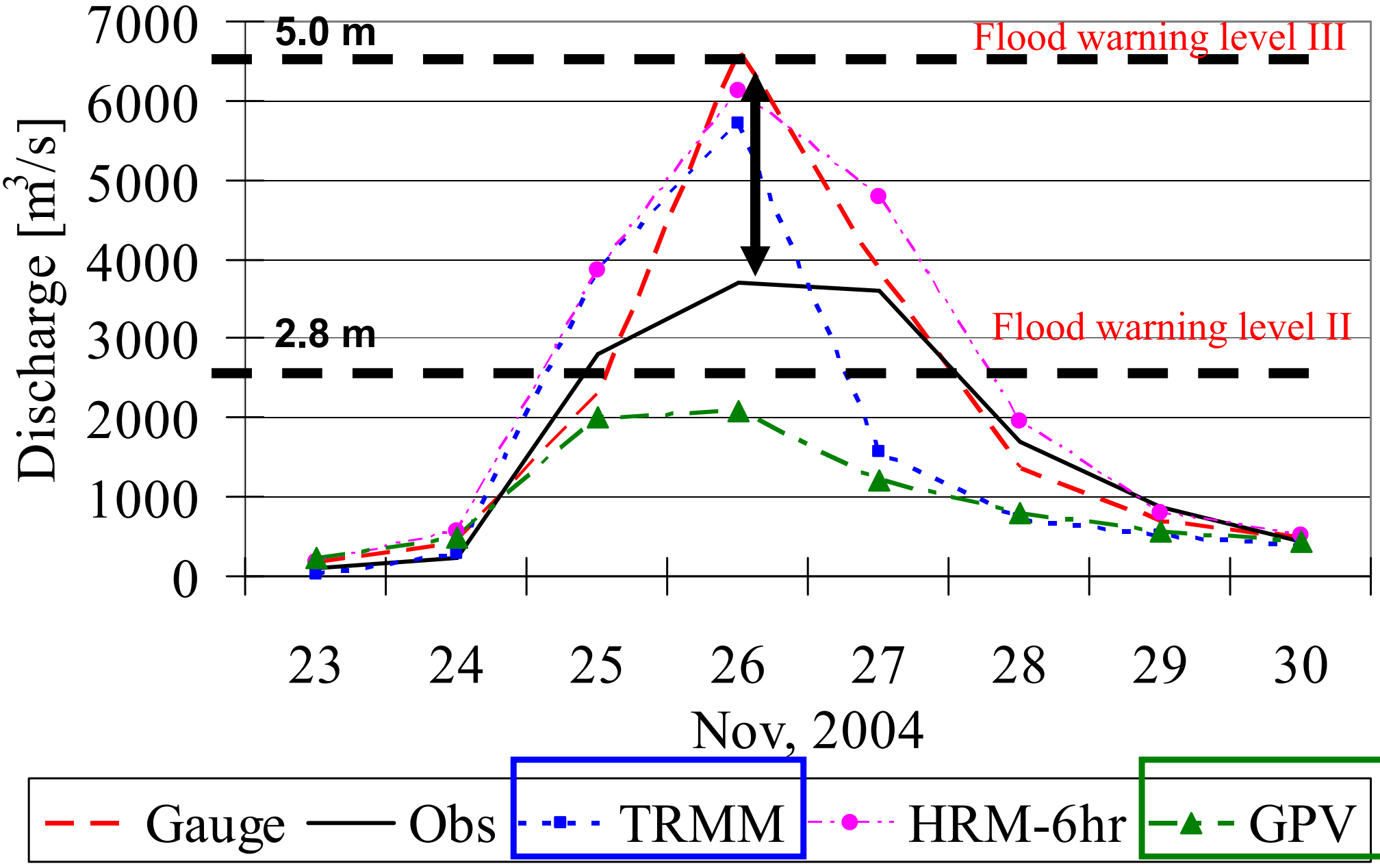




Global Satellite TRRM, 3hr, 0.25˚
Nov 1997~
TRMM focuses mainly in tropical area

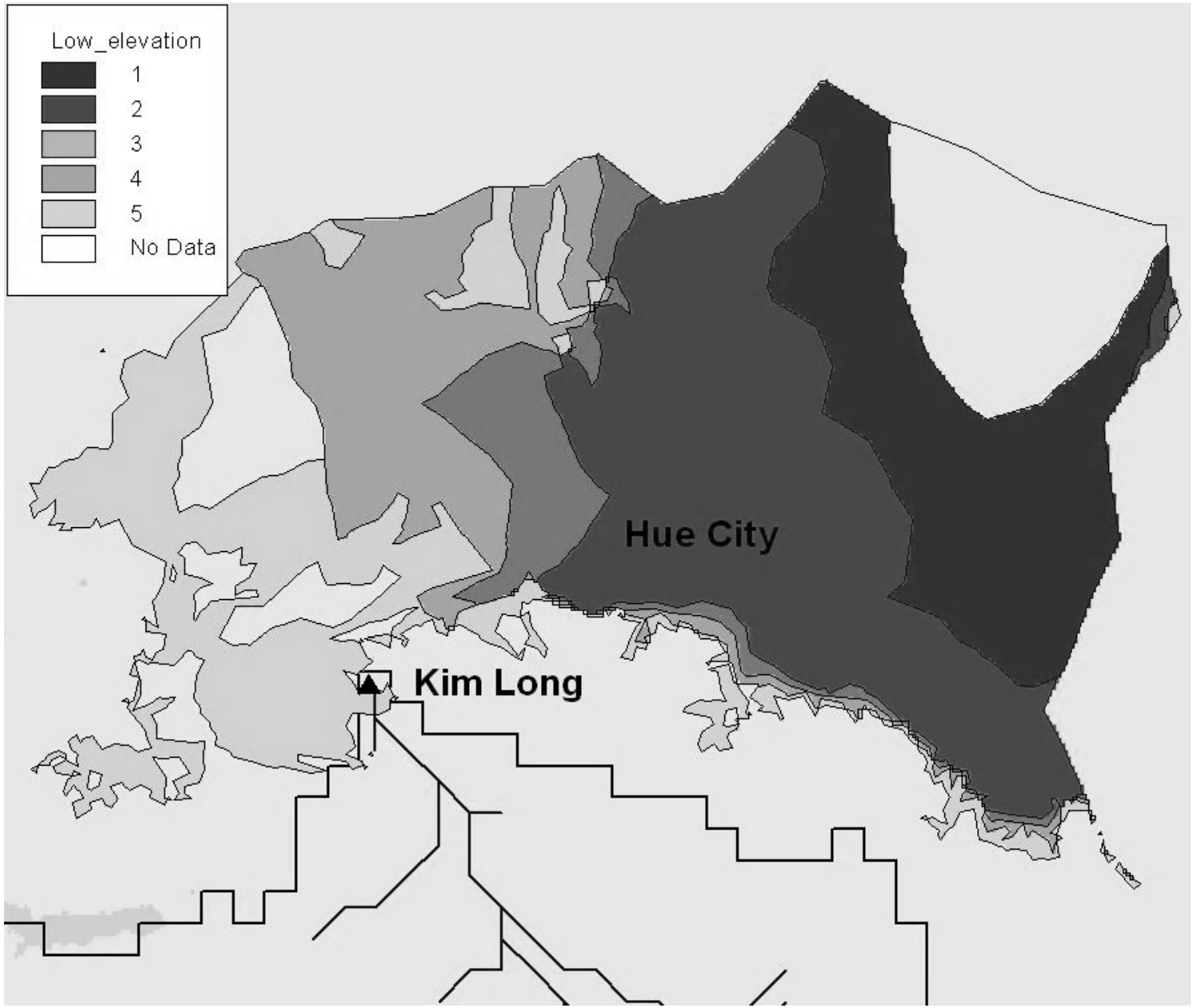
GPM, 3hr, 0.1˚
will reach 95%

High Flows Simulation



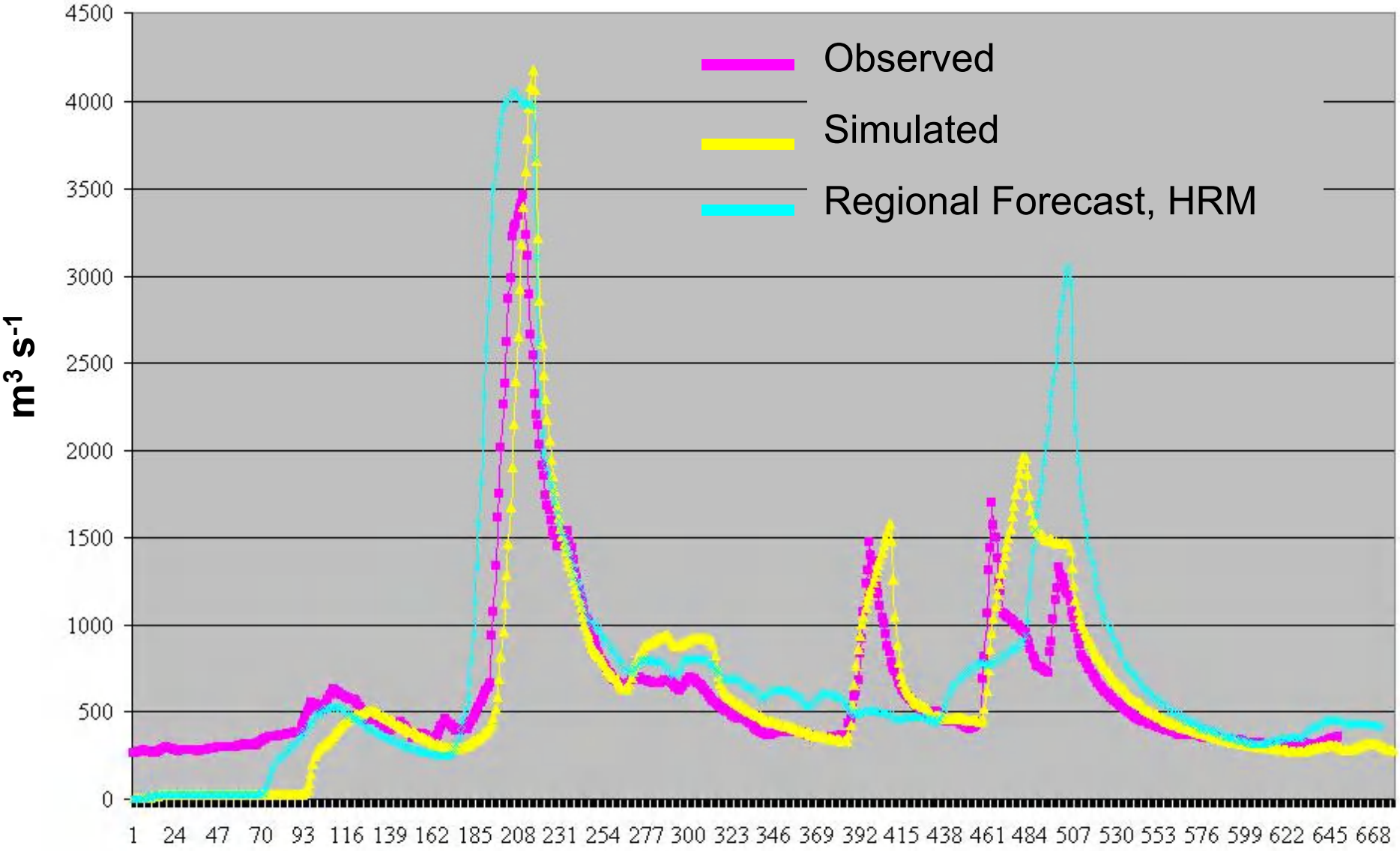
Saavedra, Koike et al., 2009

Inundation areas in Hue City



Saavedra, Koike et al., 2009

Results obtained by Vietnamese Forecasters @ MONROE/NHMS



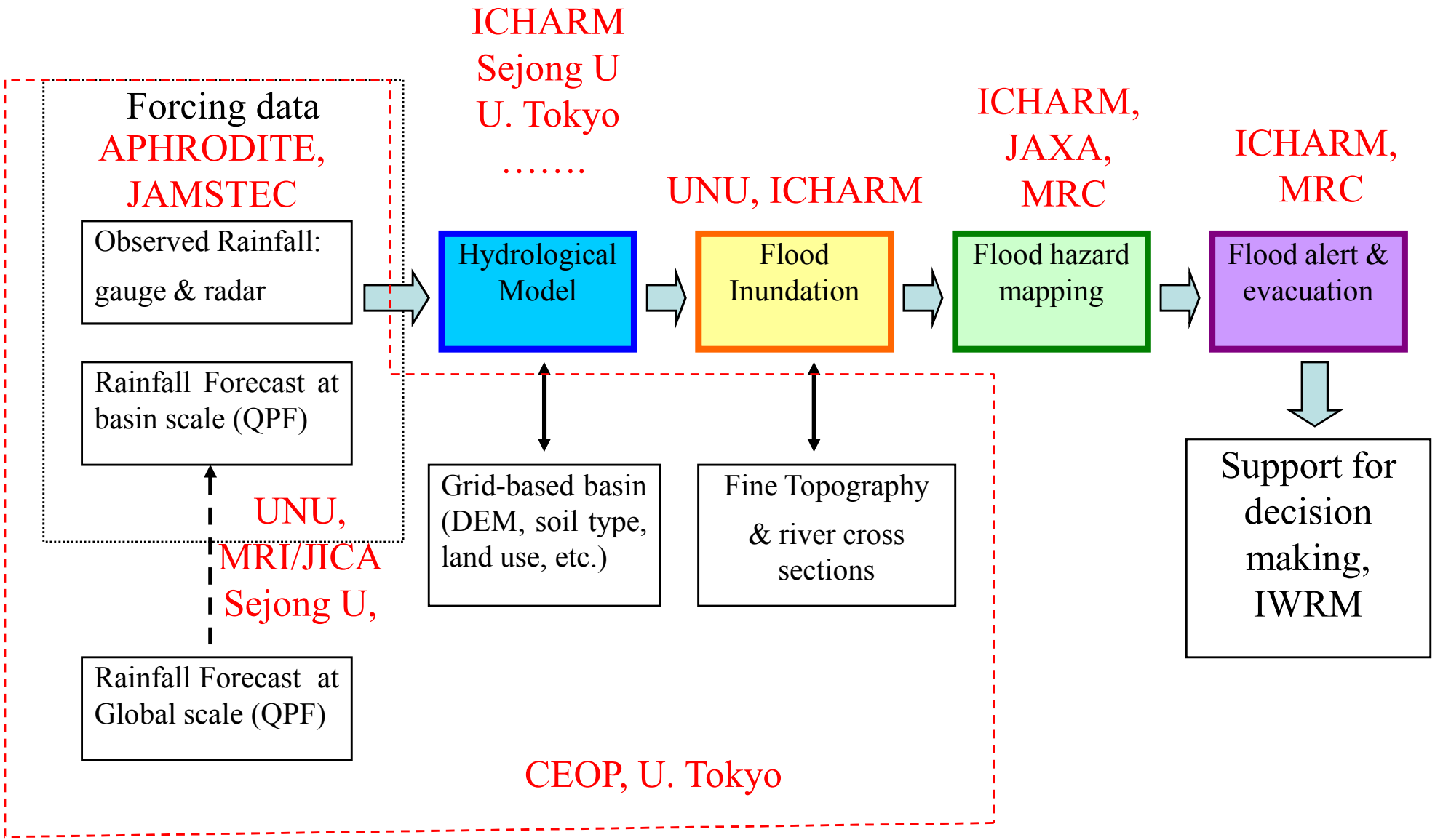
Summary

- According to the needs in Flood damage reduction, it is proposed two systems:
  - Dam Release Support System (DRESS)
  - Flood Warning Support System (FLOWSS)
- DRESS systems show efficiency in reducing floods and increasing water storage where dams are available; while FLOWSS can be used for emission of flood warning.
- QPF, real-time satellite precipitation and on-site observation were used to feed the systems
- It was possible to extend the lead-time which is crucial for sound decisions in water resources management

Next steps for the systems

- Application of customized versions of DRESS & FLOWSS systems to needed demo basins for real-time operation
- Exploit of Satellite observations e.g. GSMaP
- Include other forcing in the ensemble besides precipitation
- Include economic costs directly in the systems using the value of water allocation or false alarm warning in the cost functions

Location of CB Training Modules



Capacity Building Programs

1) Country level capacity building targeting local audience (Bandung, July 2008; China, 2009)
2) Specific Training Modules provided by Agencies/Institutions to experts/scientists

   (Vietnam, Nov. 2008 at UT)
3) Integrated capacity at each AWCI demonstration basin targeting international participants


Thanks for your attention!
Angat Dam office