ICHARM's research activities for climate change impact analysis and adaptation: Kakushin Project & IFAS development

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1. Study on climate change impact analysis study using MRI-AM20km (Kakushin Project)
   ① Development of the hybrid quantile bias-correction method for flood runoff analysis on a river basin scale
   ② Preparation for a global hydrologic runoff analysis model with BTOP model
2. Study on climate change adaptation
   ① Development of Integrated Flood Analysis System to enhance the implementation of flood forecasting and warning system in poorly-gauged river basins, using global satellite-based rainfall and GIS data

1. Study on climate change impact analysis study using MRI-AM20km (a part of Kakushin Project)

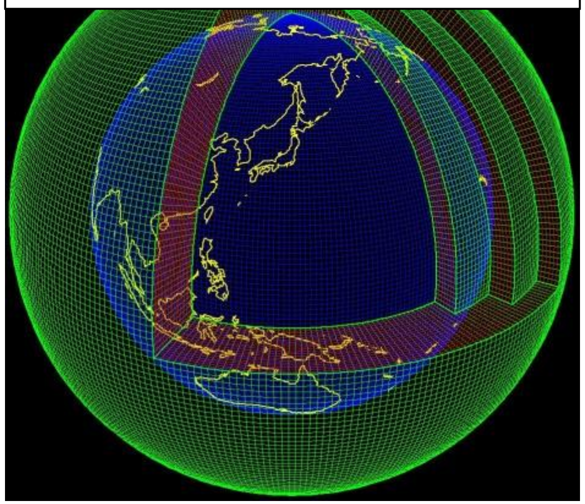
1) Development of the hybrid quantile bias-correction method for flood runoff analysis on a river basin scale

2) Preparation for a global hydrologic runoff analysis model with BTOP model

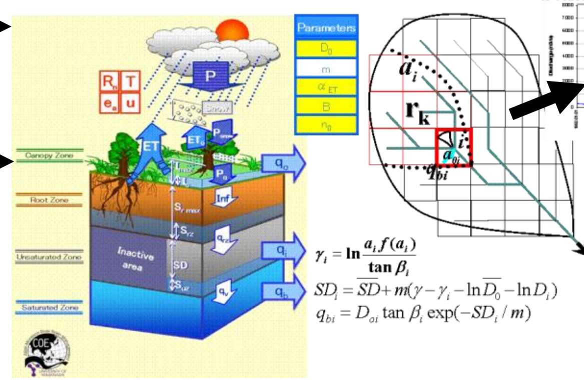
Assessment of the impact of climate change on flood disaster risk and its reduction measures over the globe and specific vulnerable areas

10–40 km mesh
global stream path

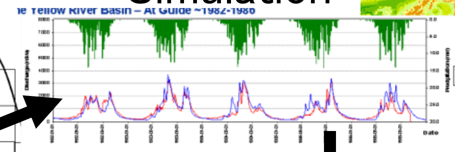
MRI–AM20km global
meteorological simulation

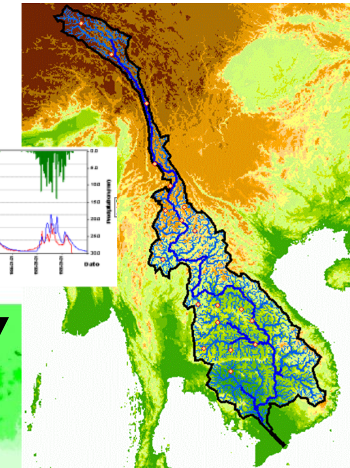


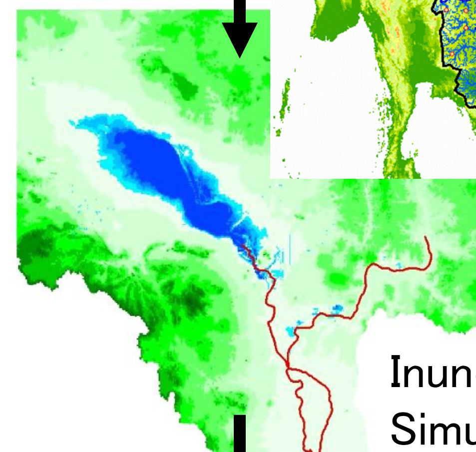
Block-wise use of TOPMODEL with Muskingum-Cunge method (BTOPMC)



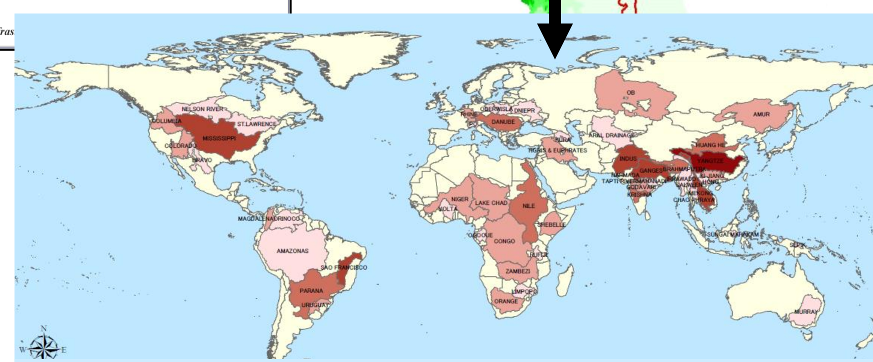
Hydrological Simulation







Inundation Simulation



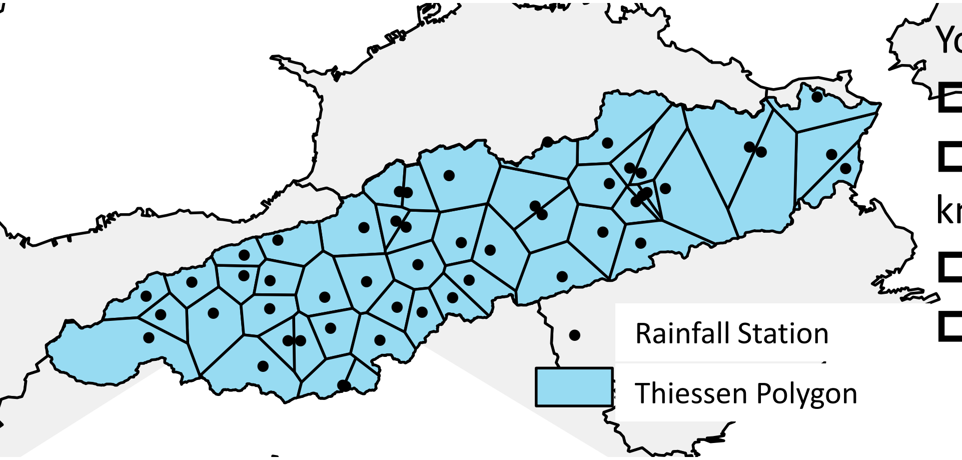
Global Flood Vulnerable Risk Map

KAKUSHIN

Innovative Program of Climate Change Projection for the 21st Century

Project Period: 2007 Apr. – 2012 Mar.

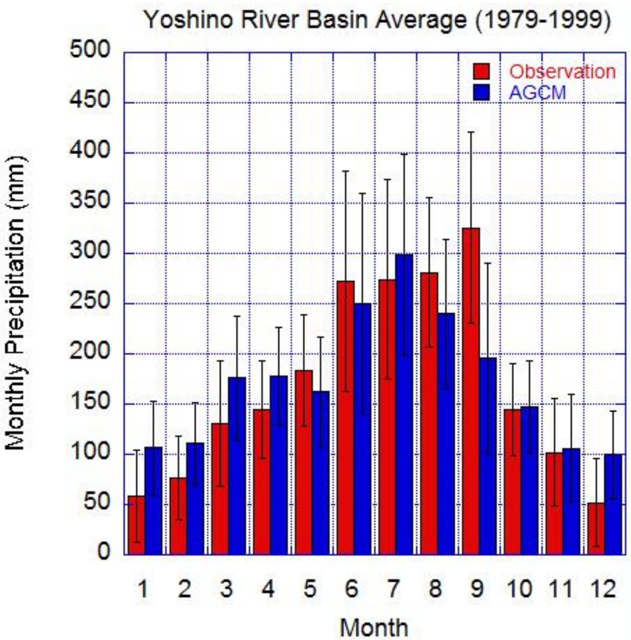
Example of comparison（Yoshino River Basin, Japan）



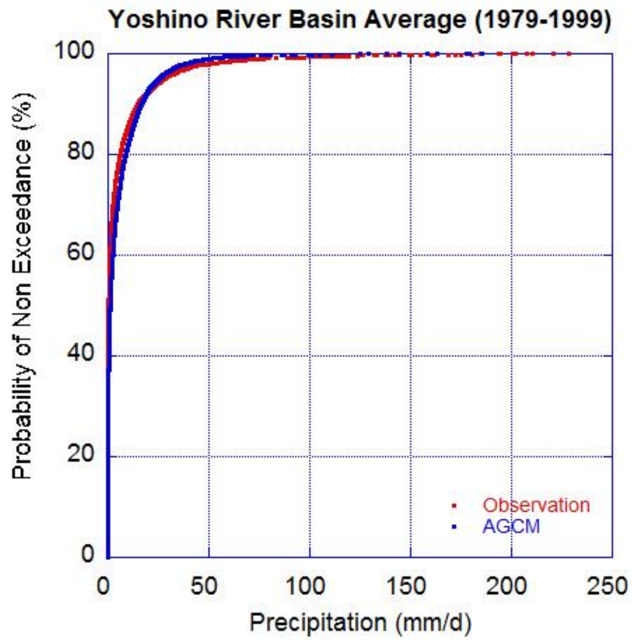
Yoshino River Basin (Japan)

- Basin Area : 3,750 km2
- Number of Rainfall Stations : 51 stations（73.5 km2/sta）
- Number of Grid of AGCM : 29
- Annual Precipitation : 1,800 mm – 2,000 mm

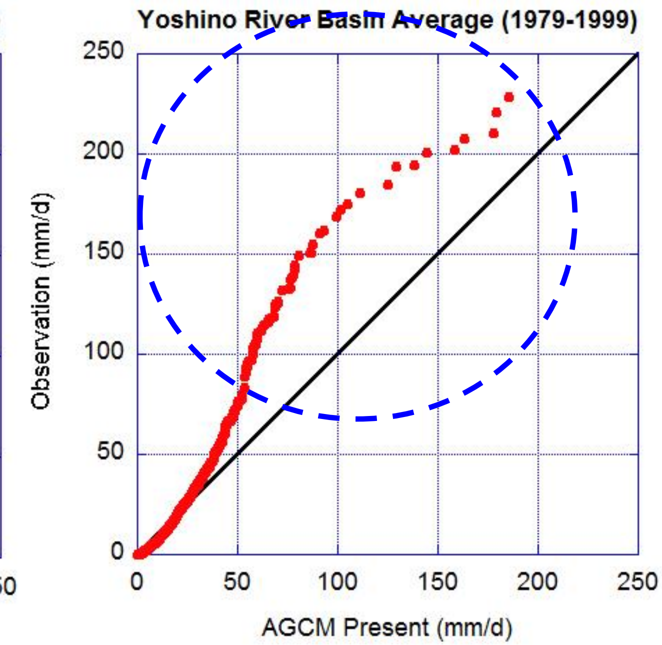
GCM20: Underestimation



Monthly Precipitation



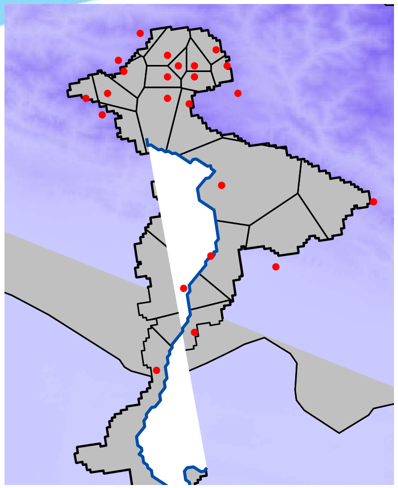
Probability of Non Exceedance (Daily Precipitation)



Quantile-Quantile Plot (Daily Precipitation)

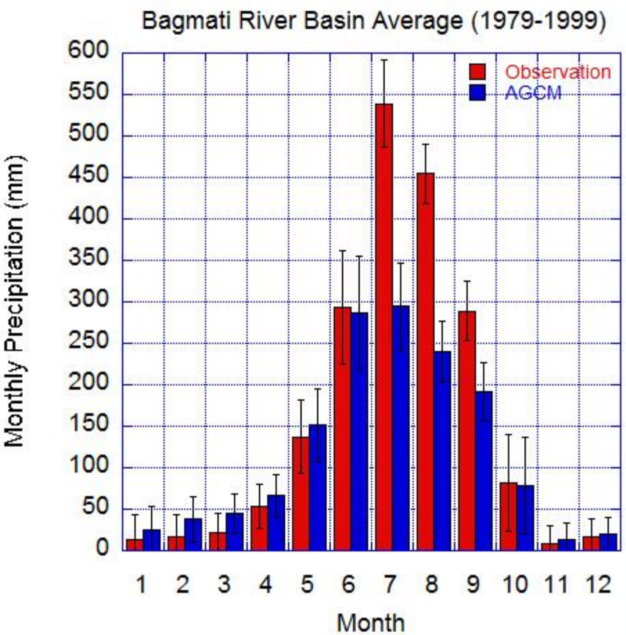
- AGCM underestimates observation for heavy precipitation.
- It is necessary to apply a correction method on AGCM precipitation data for flood analysis.

Example of comparison（Bagmati River Basin, Nepal）

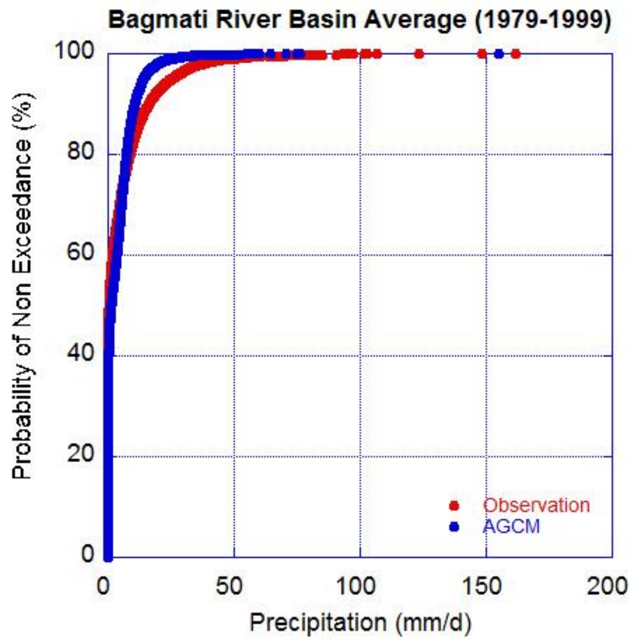


Bagmati River Basin

- ❑Basin Area：4,760 km2
- ❑It can be clearly divided into rainy (Jun. to Oct.) and dry (Nov. to May) season.
- ❑Number of rainfall stations: 23 stations（207 km2/sta）
- ❑Number of AGCM grid: 29
- ❑Annual Precipitation: 1,800 mm – 2,000 mm

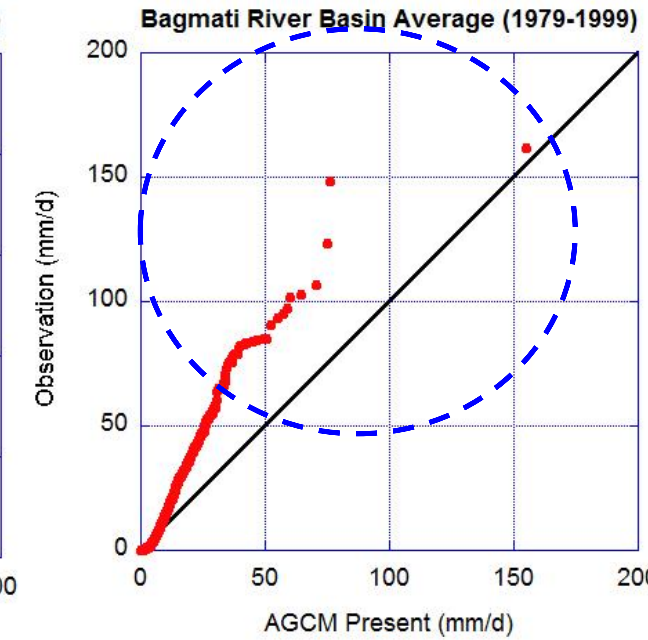


Monthly Precipitation



Probability of Non Exceedance
(Daily Precipitation)

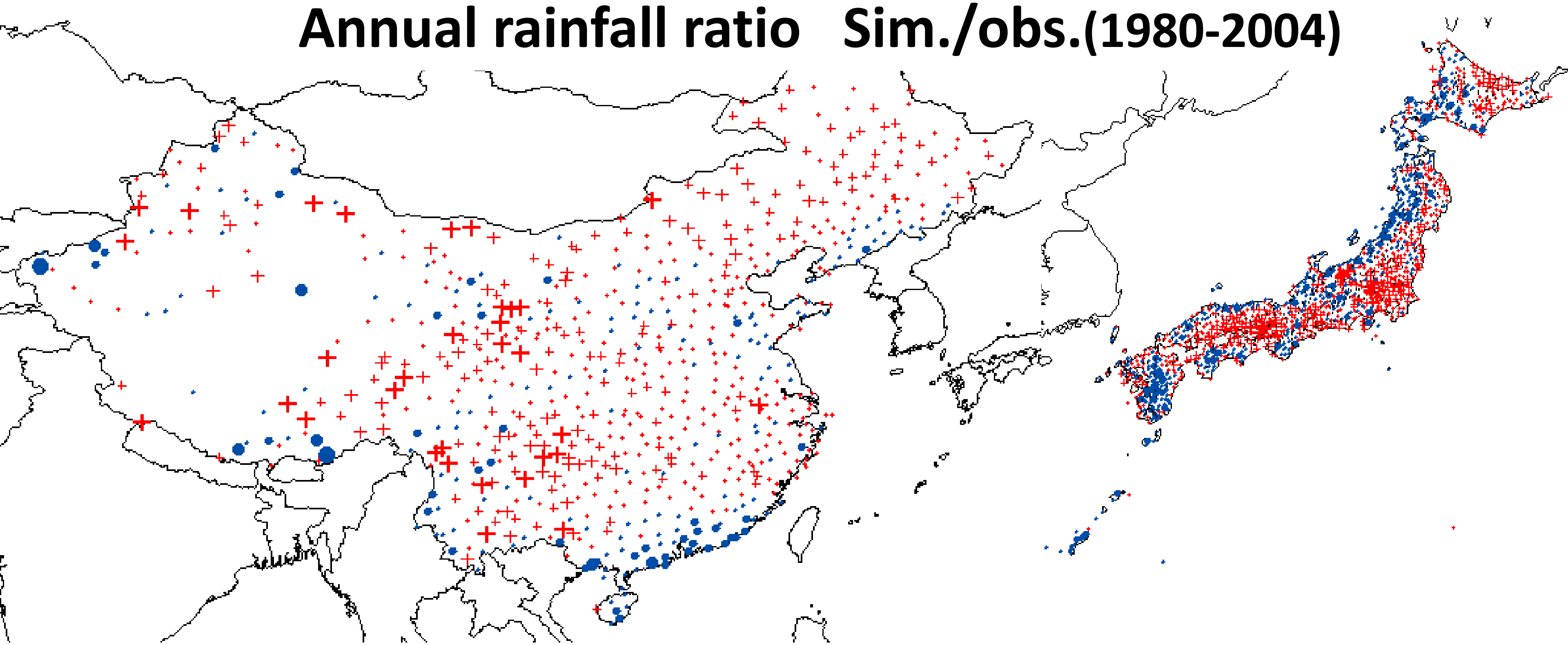
GCM20: Underestimation



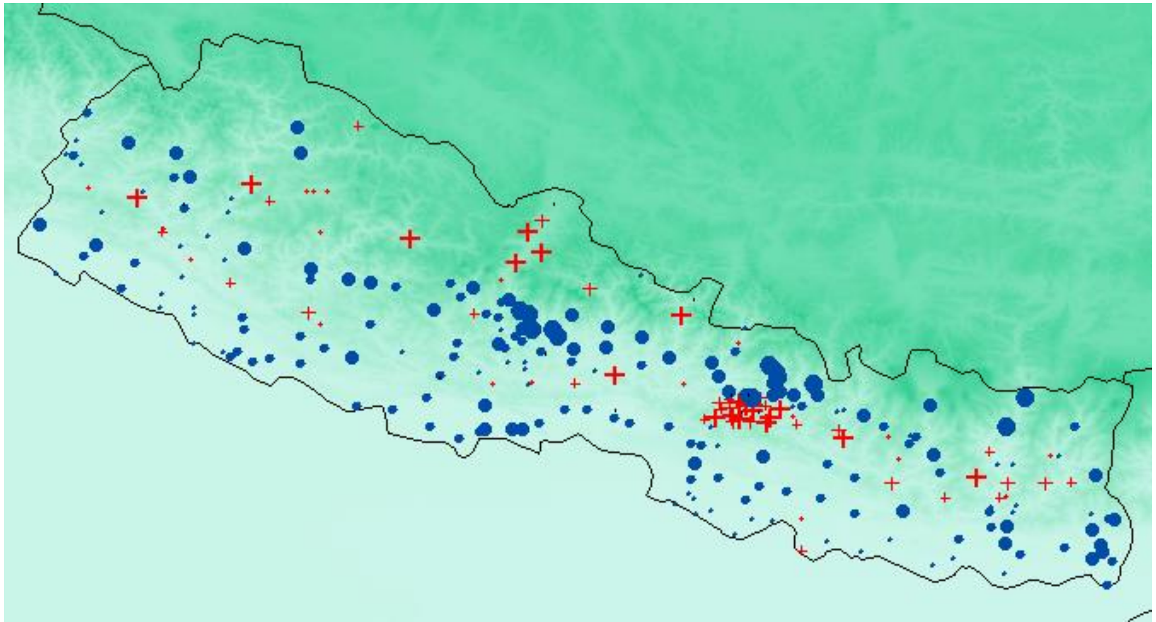
Quantile-Quantile Plot
(Daily Precipitation)

- ❑AGCM underestimates observation for heavy precipitation.
- ❑It is necessary to apply a correction method on AGCM precipitation data for flood analysis.

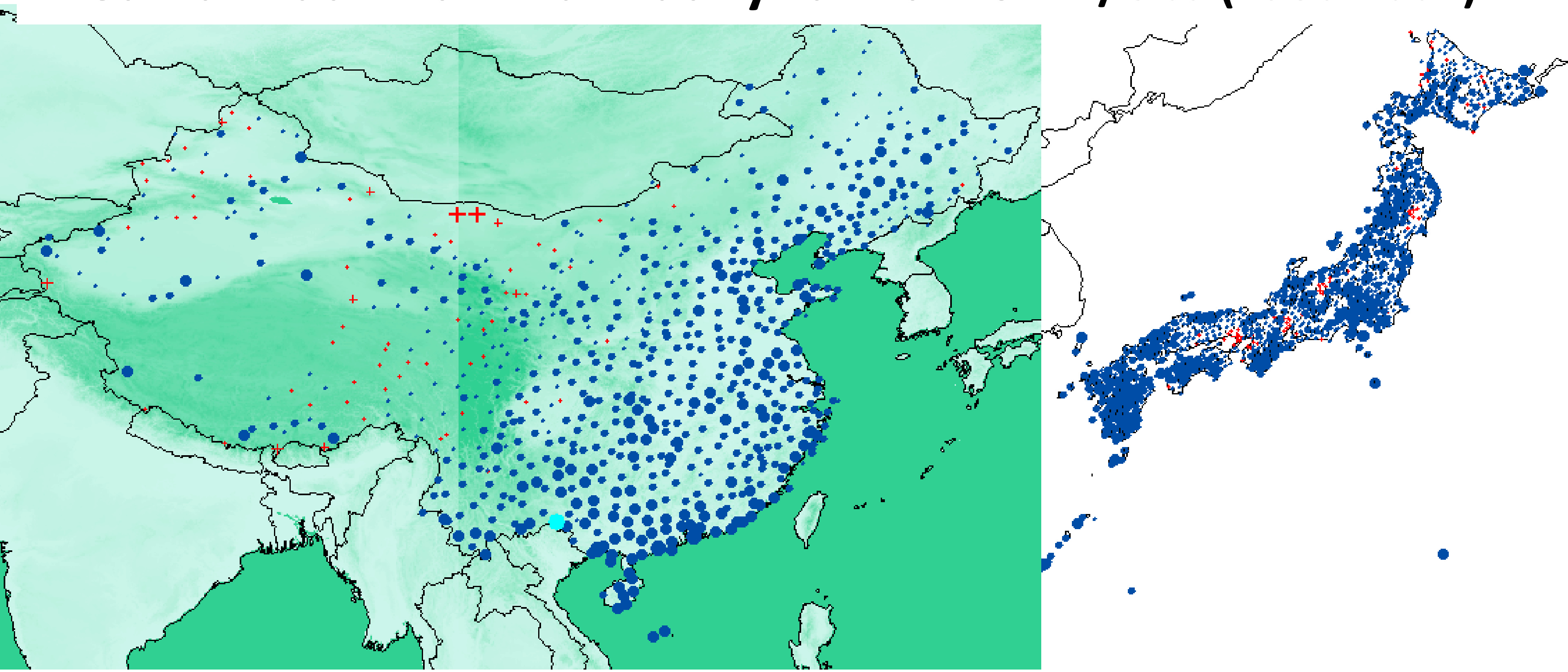
Annual rainfall ratio Sim./obs.(1980-2004)



Red : **Overestimated**
Blue : **Under-estimated**

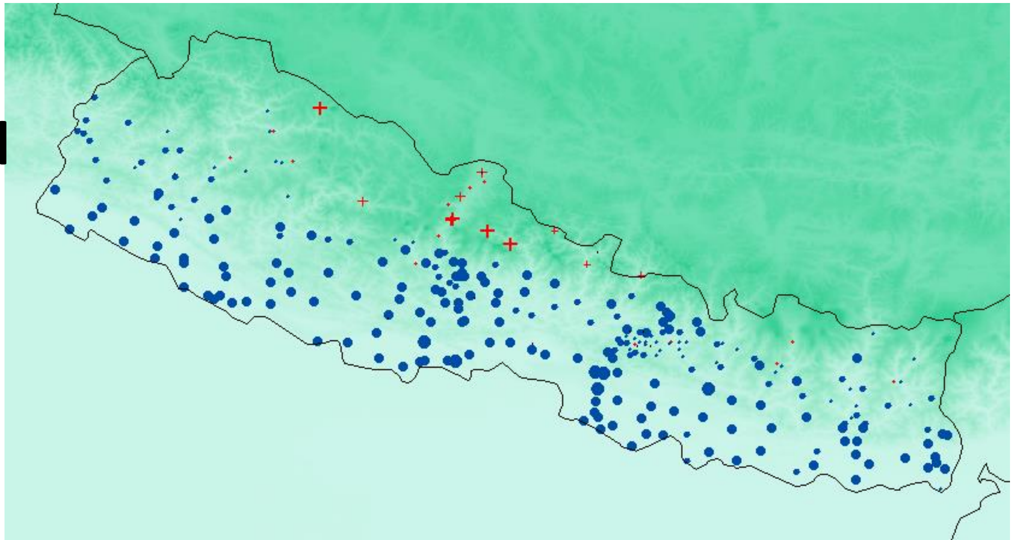


Mean annual maximum daily rainfall Sim./Obs.(1980-2004)



Red : Overestimated

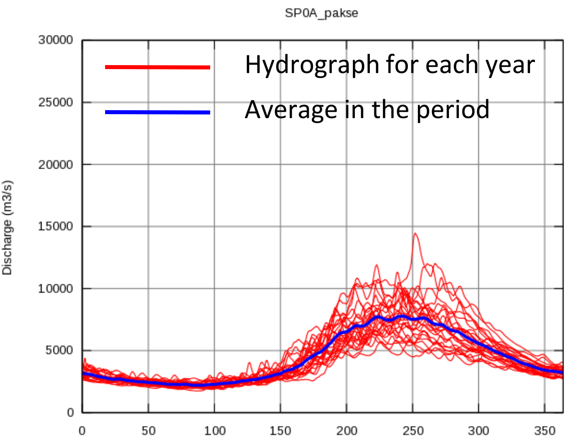
Blue : Under-estimated



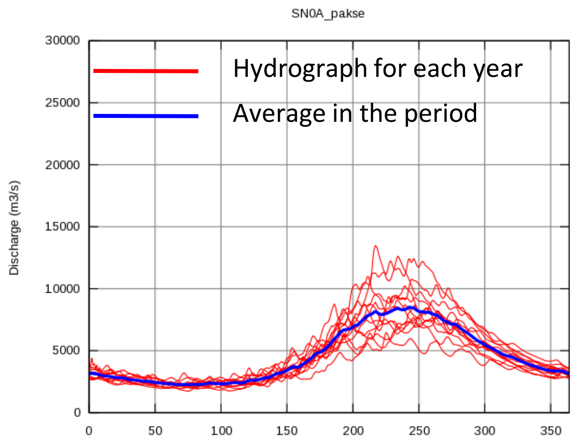
River Discharge Simulation by GCM20 Precipitation data Case of Mekong River

- River discharge simulation at Pakse
- Precipitation: Observation, GCM20 precipitation data for current, near future and future
- Temperature, cloud cover, daylight duration, radiation, vapor pressure, wind speed: CRU Reanalysis
- BTOPMC model parameter values are determined based on globally available data and calibration.

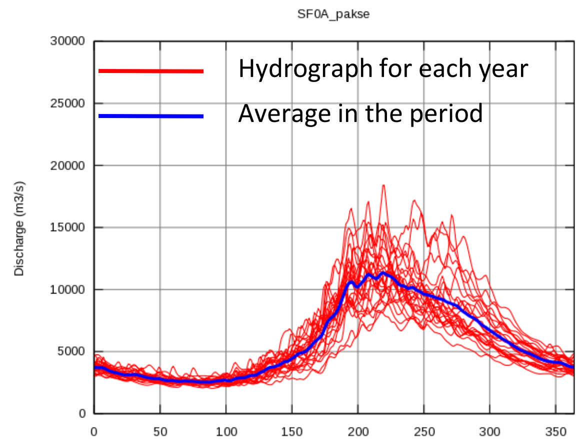
Current(1979-2004)

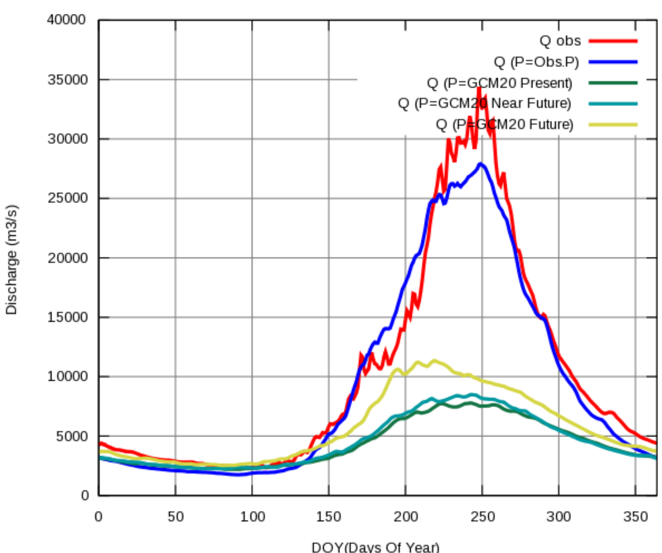


Near Future (2015-2027)



Future (2075-2099)





■River discharge at Pakse may increase under climate change condition but…

■There is a big difference between the observed discharge and simulated discharge by GCM20 precipitation data. …Underestimation

<u>Necessity of a correction method of GCM20 precipitation data</u>

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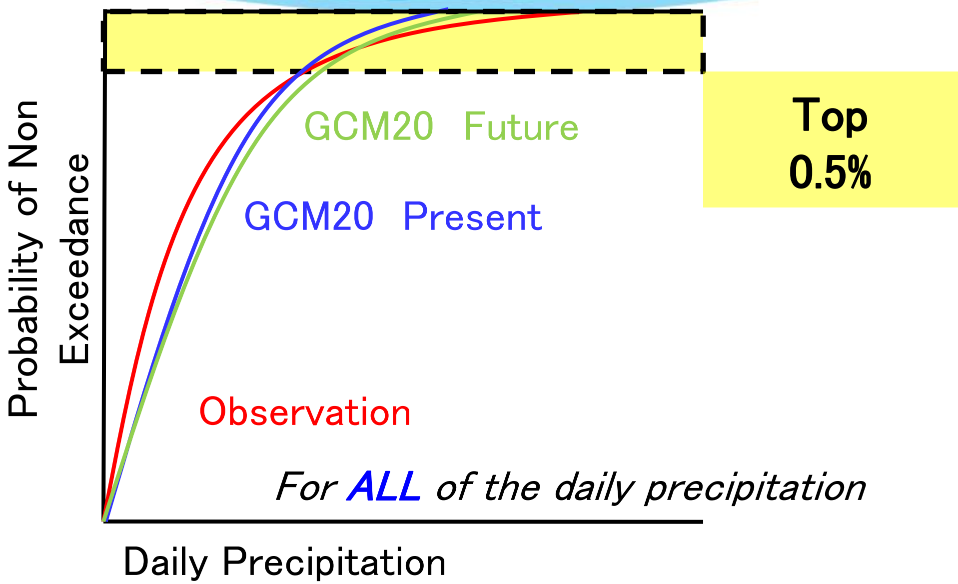
Concept of bias correction method for GCM20

Hybrid Method

A) Extreme Value
⇒The samples in top 0.5% of prob. of non exceedance are considered.

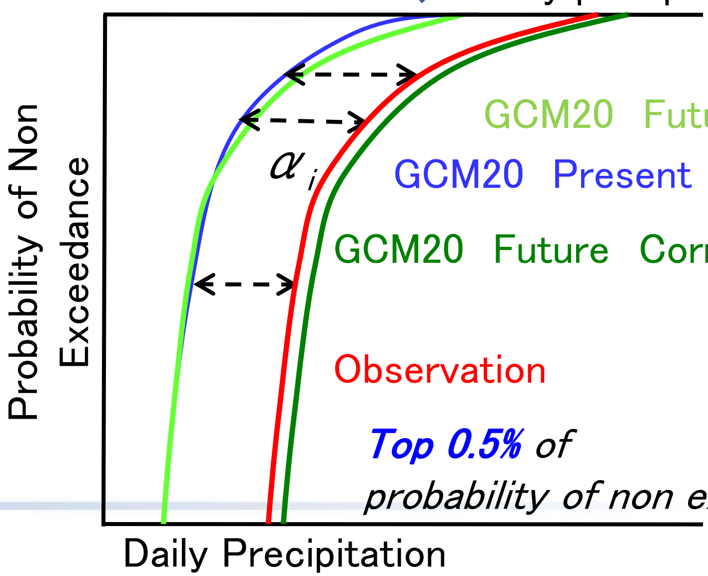
B) Other value
⇒They are divided into each month.



①The samples in top 0.5% on probability of non exceedance for observation, GCM20 Present and GCM20 Future are subtracted.

Abstraction of top 0.5% daily precipitation

②The ratio for same rank. (α_i) between observation (P_Obs_i) and GCM20 Present ($GCM20\_Pre_i$) is estimated. α_i is regarded as a correction coefficient for each rank and multiplied to the value of GCM20 Future of same rank ($GCM20\_Fut_p$) and corrected value (P_Fut_p) is obtained.



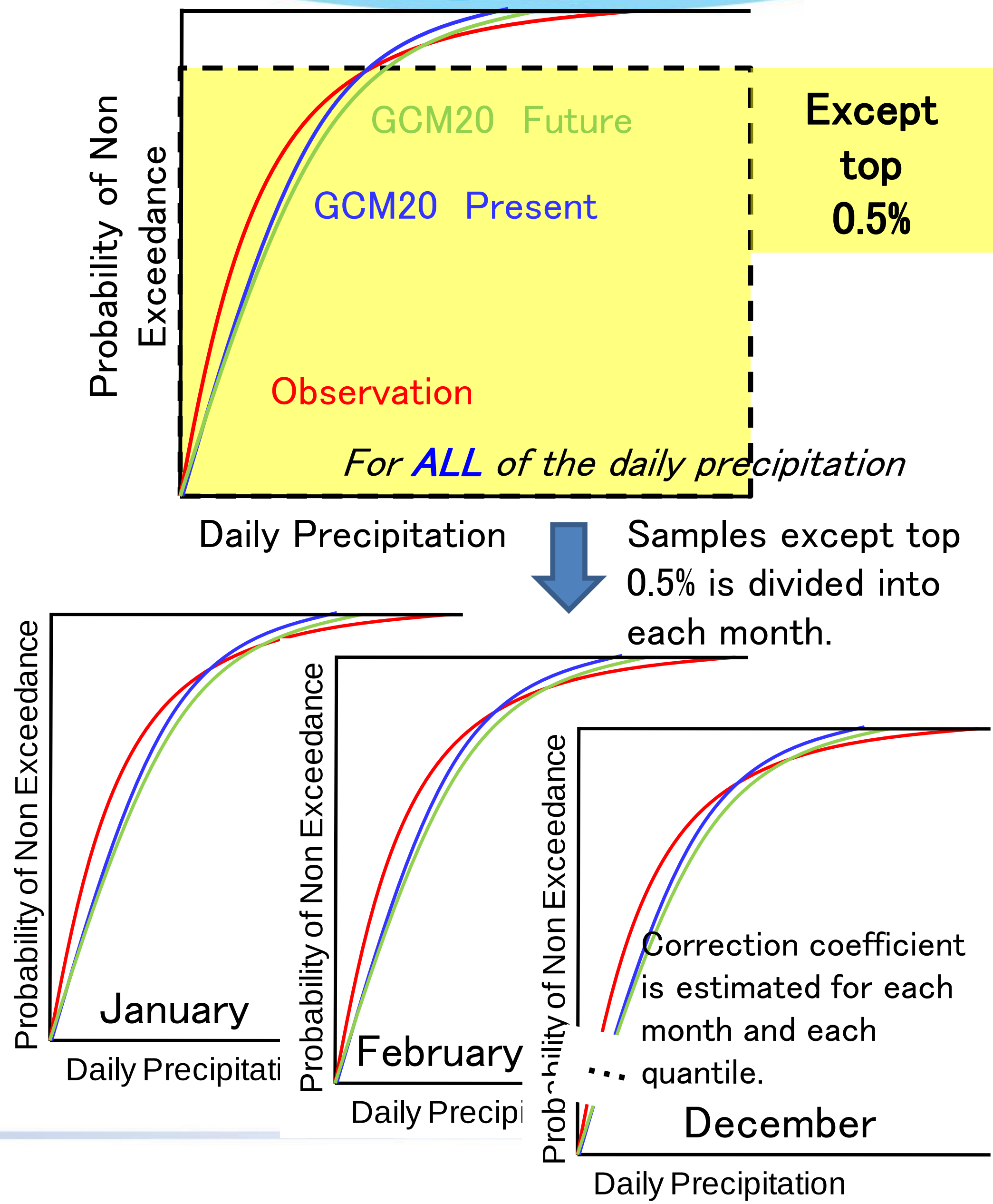
$$\alpha_i = \frac{P\_Obs_i}{GCM20\_Pre_i}$$

$$P\_Fut_i = \alpha_i \times GCM20\_Fut_i$$

Concept of bias correction method for GCM20 (continue)

Hybrid Method

③Samples except top 0.5% on observation, GCM20 Present and Future are divided into each month.

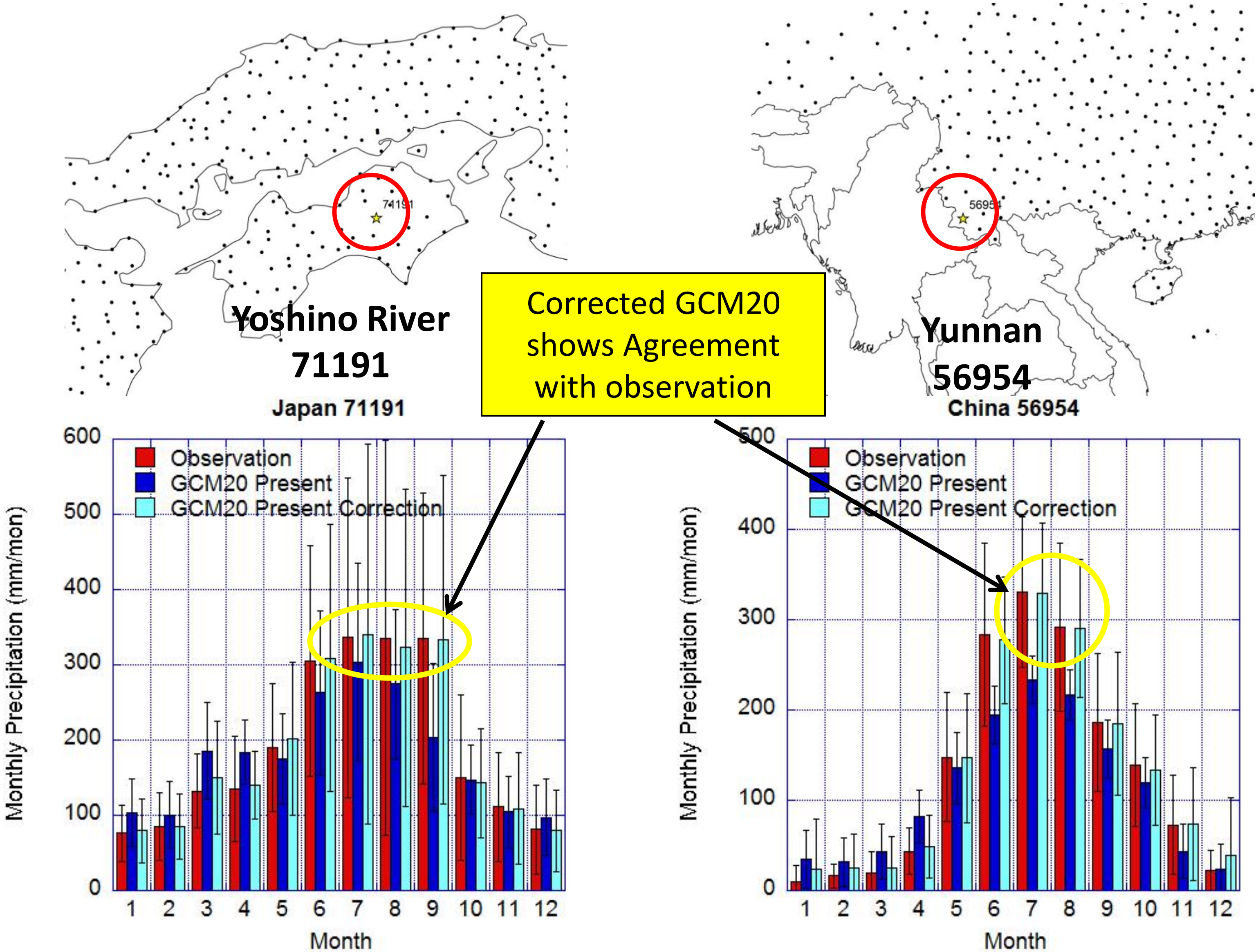


④The ratio between observation ($P\_Obs_{m\_i}$) and GCM20 Present ($GCM20\_Pre_{m\_i}$) is estimated for each month and each rank (α_{m_i}). α_{m_i} is regarded as correction coefficient and multiplied to GCM20 Future of same month and same rank ($GCM20\_Fut_{m\_i}$) and corrected value ($P\_Fut_{m\_i}$) is obtained.

$$\alpha_{m\_i} = \frac{P\_Obs_{m\_i}}{GCM20\_Pre_{m\_i}}$$

$$P\_Fut_{m\_i} = \alpha_{m\_i} \times GCM20\_Fut_{m\_i}$$

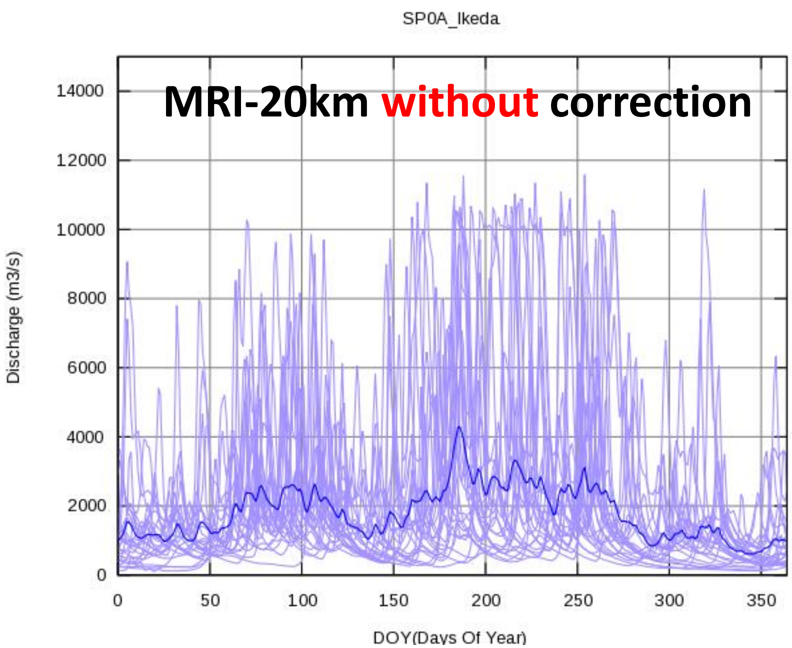
Result of correction method (Japan, China, each 1 point)
Verification of present climate condition, *Monthly Precipitation*

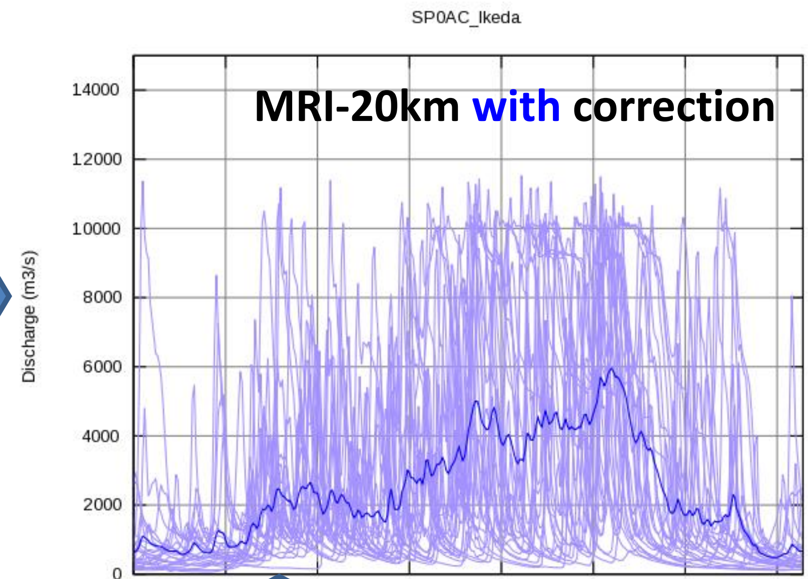


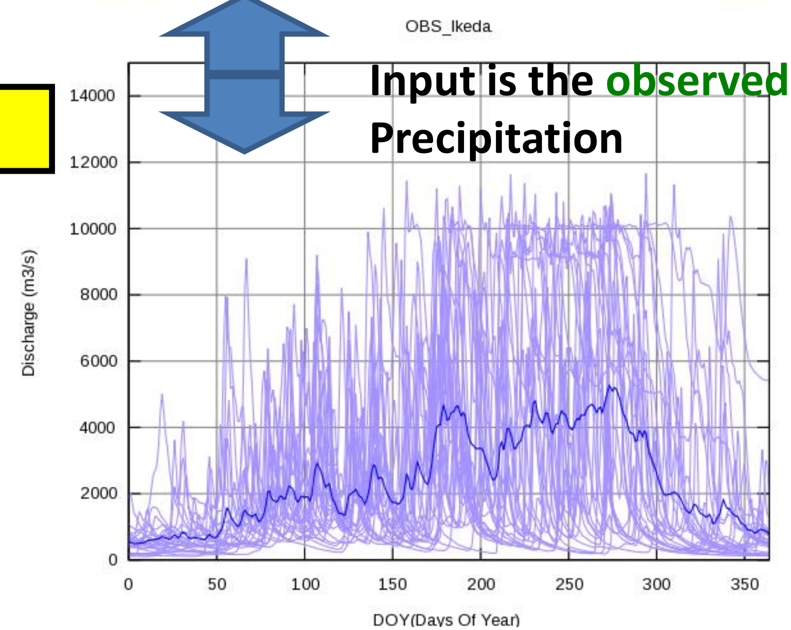
Average of 1980-2004 (25 Years)

Average of 1979-2000 (22 Years)

Effect of the bias correction method for river discharge simulation for the Ikeda station of the Yoshino River, Shikoku, Japan



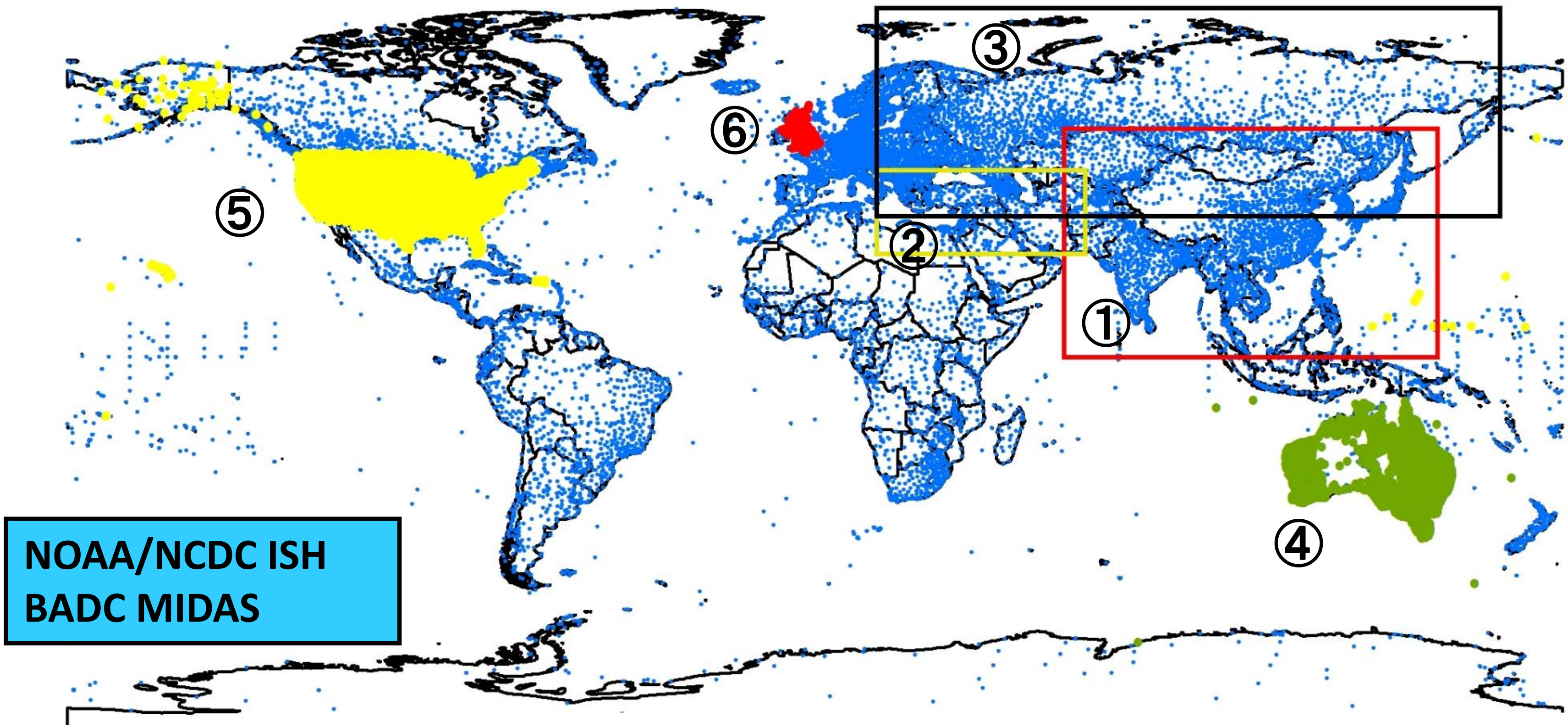




Present climate condition（1980-2004)

■The runoff analysis **with** correction method shows lower discharge in winter and higher discharge in summer compared with the result **without** correction method.
→ This is just more coincident with the runoff analysis with **observed** precipitation.

Collection of observed daily rainfall data



APHRODITE (Yatagai)

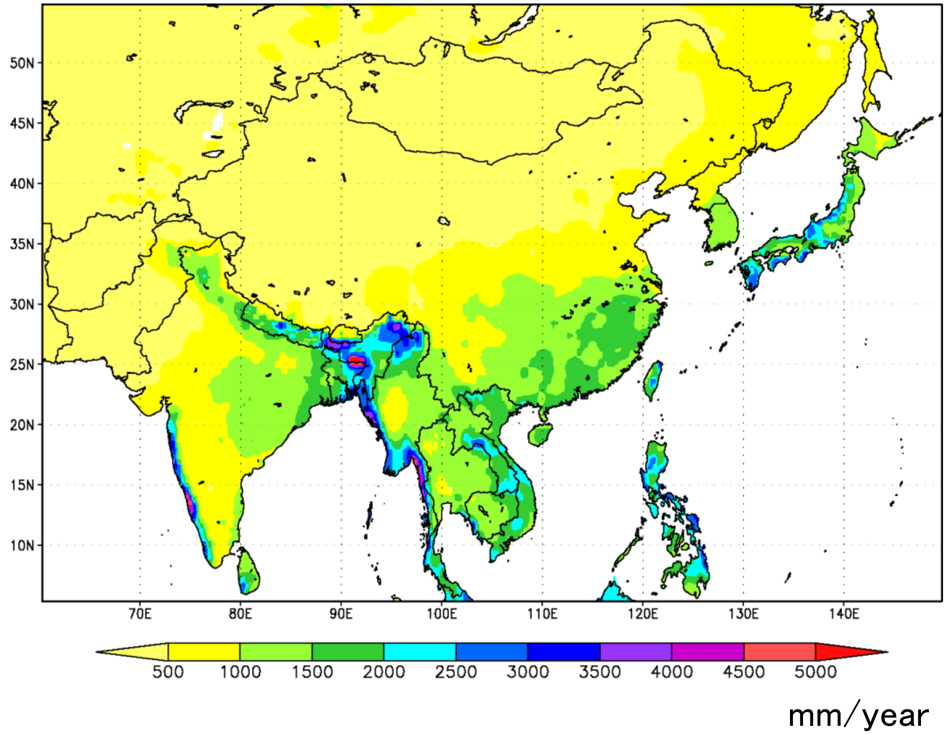
Number	Country
1	APHRODITE Monsoon Asia
2	APHRODITE Middle East
3	APHRODITE Russia

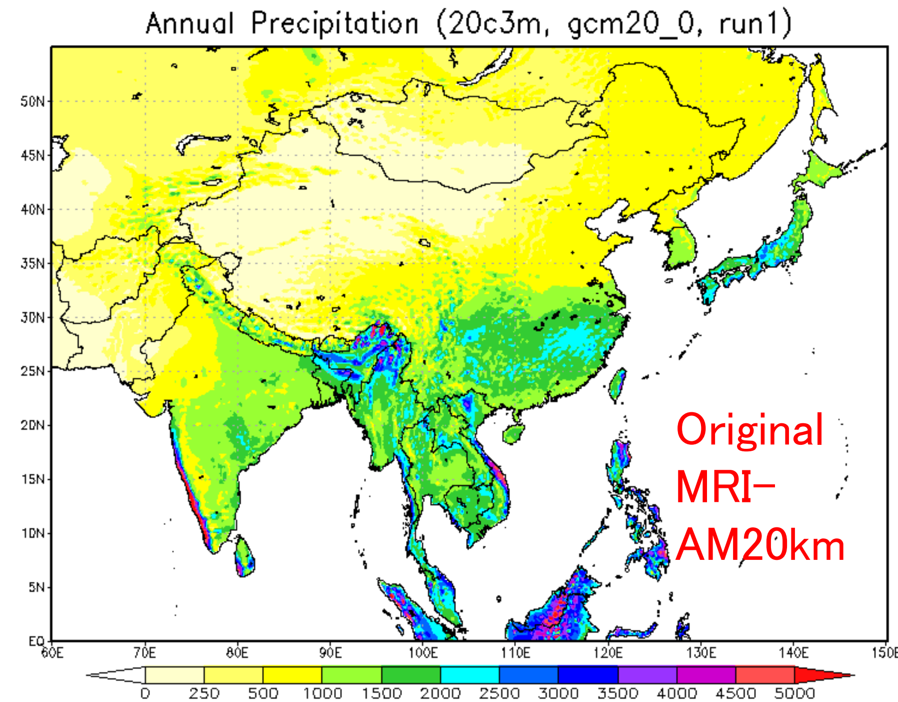
Data collected from individual national meteorological organization

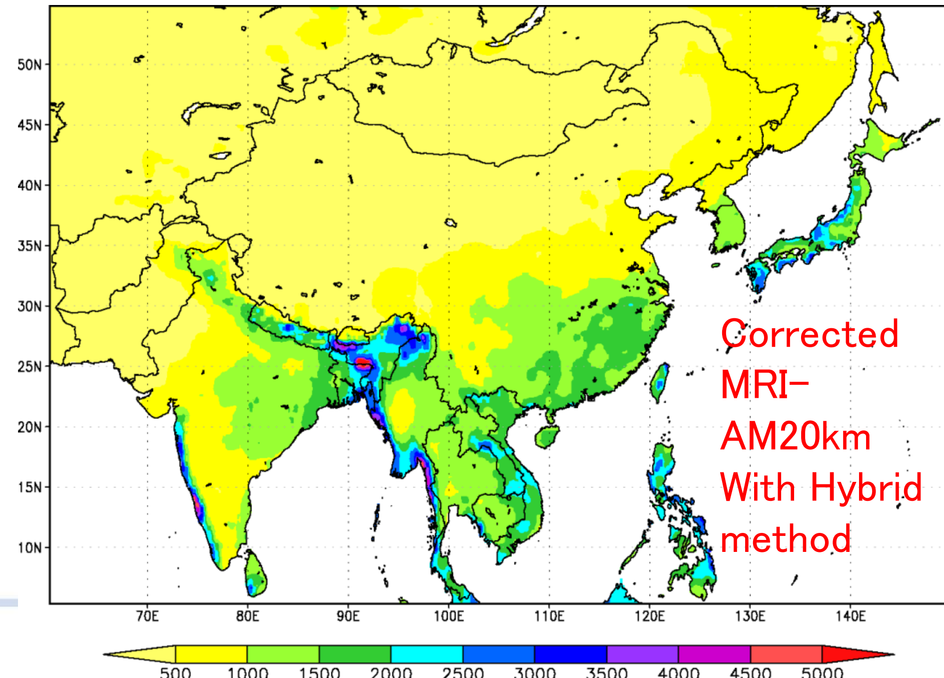
Number	Country	N of Stations	Area (km²)	Area per station (km²/sta)
4	Australia	4,520	7,686,850	1,700
5	U.S.A	6,206	9,626,630	1,551
6	U.K	193	244,820	1,268

Effect of Hybrid Bias Correction for MRI-AM20km -Mean annual precipitation-

APHRODITE MA
(25 years：1980-2004)





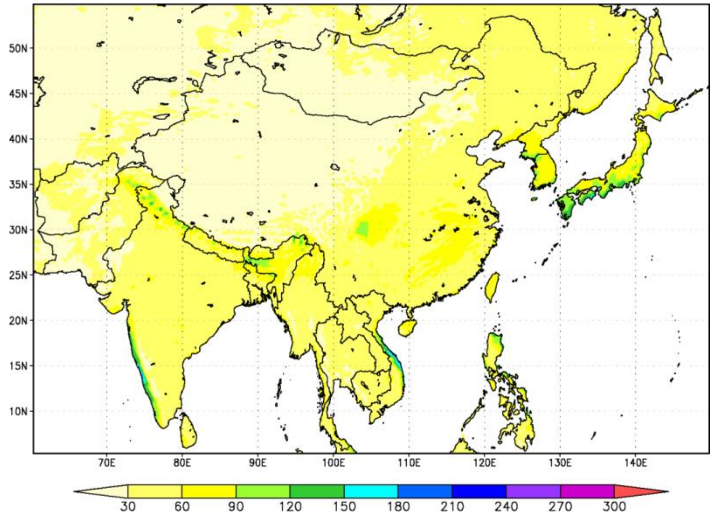


- The method is simple and therefore applicable such large domain easily.
- The corrected GCM20 shows almost same distribution with observation (APHRODITE MA).

Effect of Hybrid Quantile Bias Correction for MRI-AM20km
-Annual maximum daily rainfall (25-year mean)-

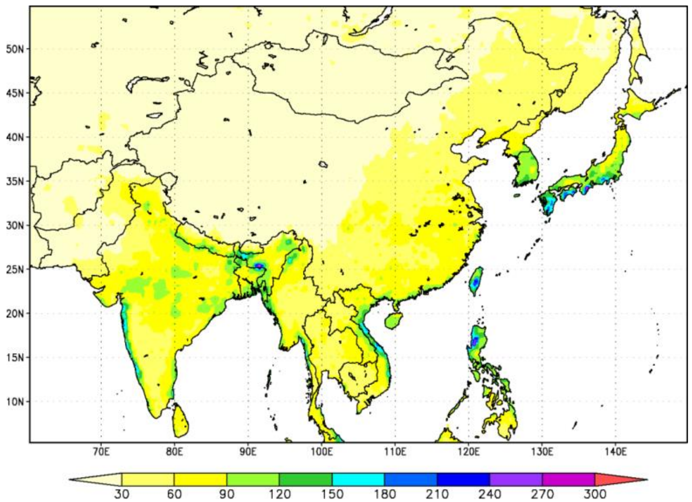
MRI-AM20km underestimate annual maximum daily rainfall in many regions

Original MRI-AM20km
(1980-2004)



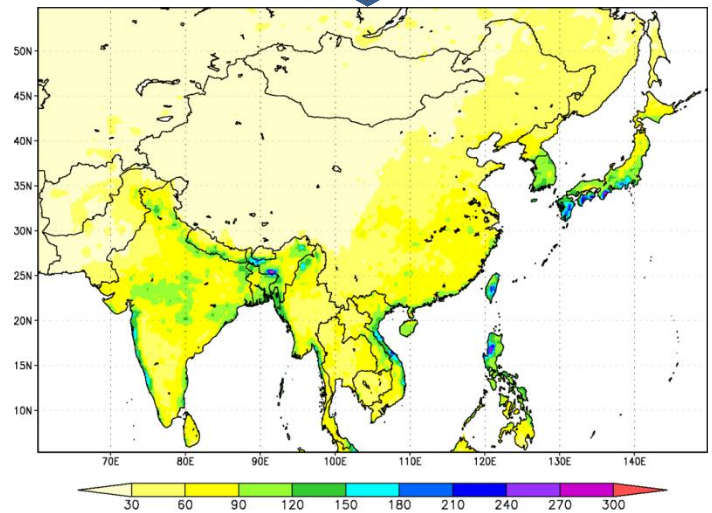
mm/day

APHRODITE MA
(25 years:1980-2004)



mm/day

Corrected MRI-AM20km With Hybrid method
(1980-2004)



mm/day

Bias corrected ones shows good agreement with observed database.

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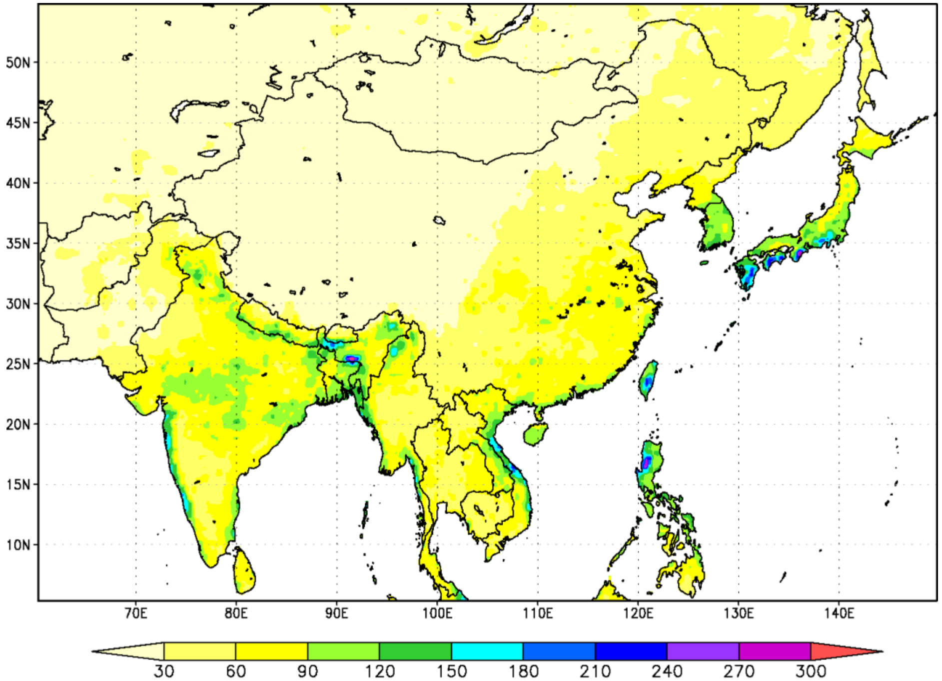
Effect of Hybrid Quantile Bias Correction for MRI-AM20km

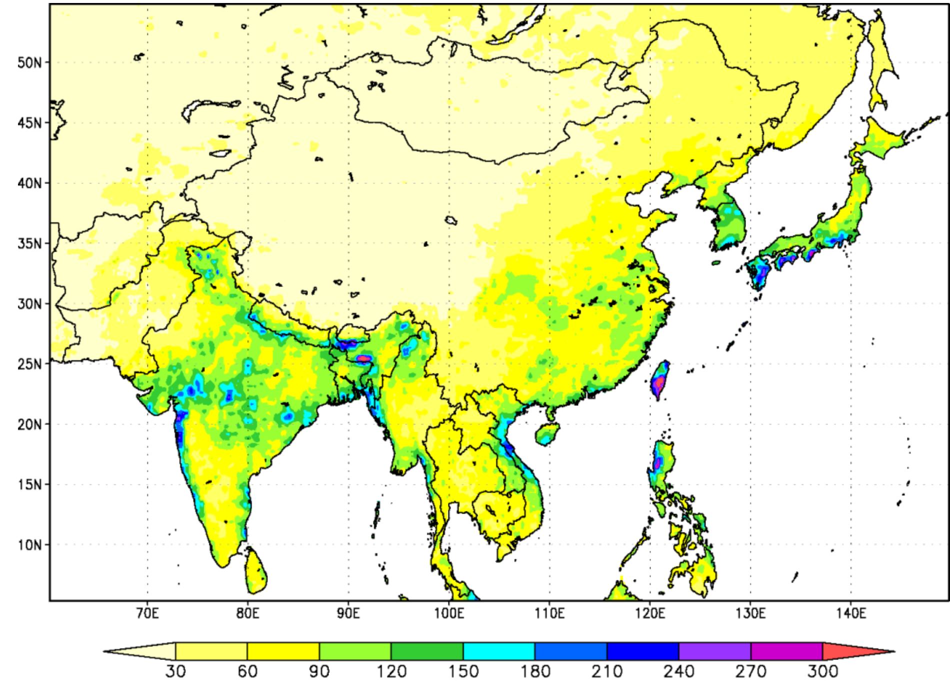
-Future projection of annual maximum daily rainfall-

Corrected MRI-AM20km
(Present climte：1980-2004)



mm/day

Corrected MRI-AM20km
(Future climte： 2075-2099)



mm/day

- The future projection of 25-year mean annual maximum rainfall is increased in many regions, especially in the southeastern part of China and the middle part of India.

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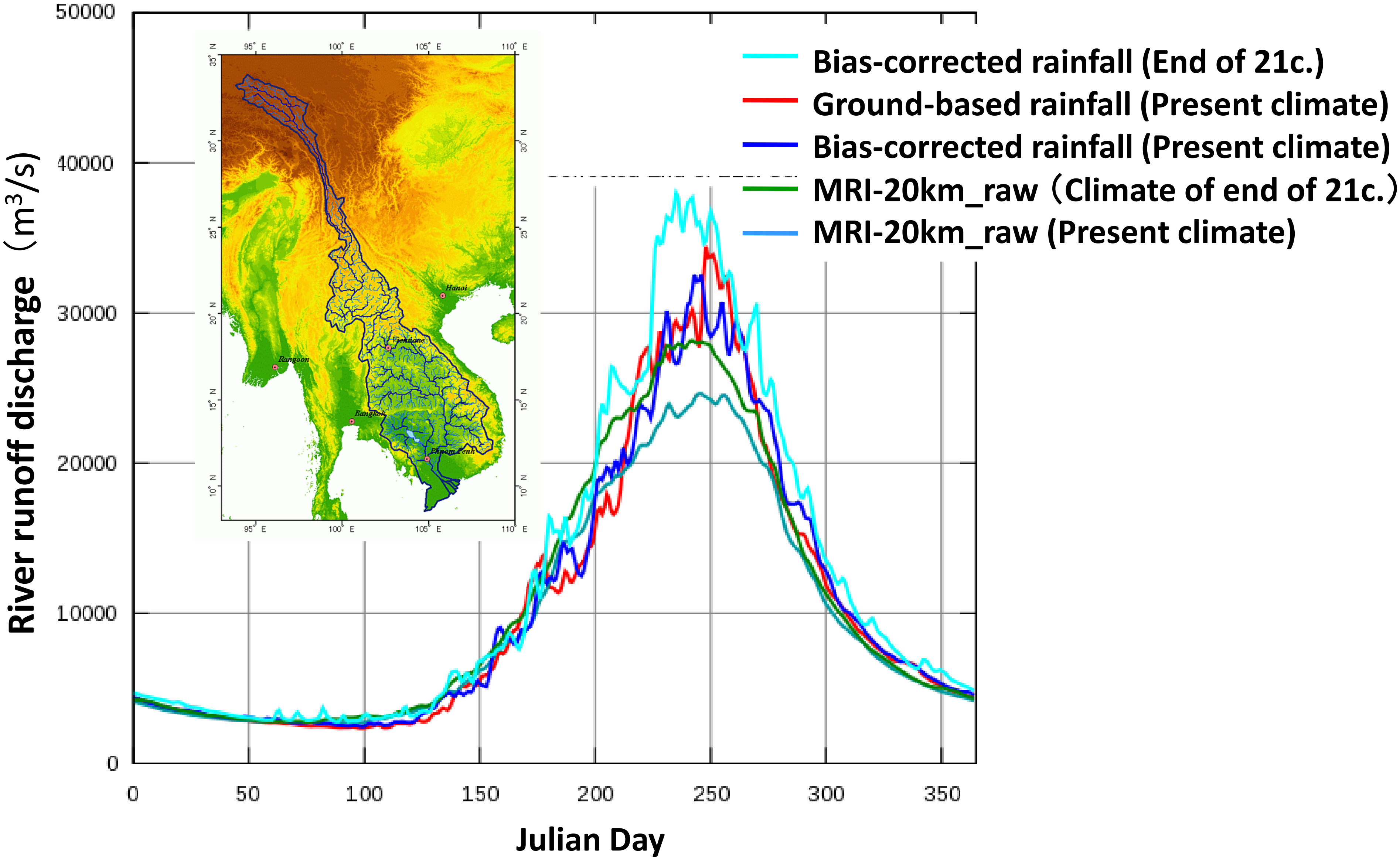
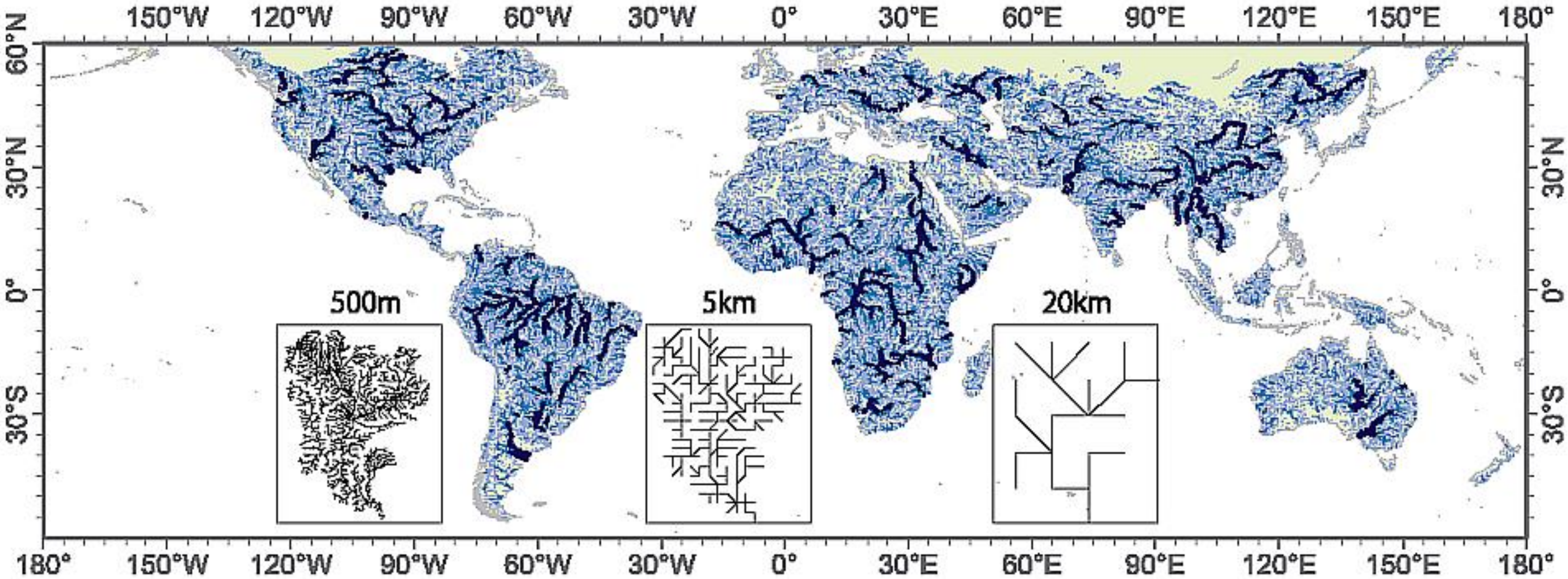
Effect of Hybrid Quantile Bias Correction Method

- Flood runoff analysis (A case for continental river: Mekong)-



Scale-Free River Network Dataset



By WWF based on 90m resolution HydroSheds data.
Preserves the original topographical information in all grid scales.
Black : Example of rivernetwork with different resolutions
Blue (background): Rivernetwork with 20 km resolution
(Magome *et.al.*, 2010, Submitted to Hydrological Research Letters)

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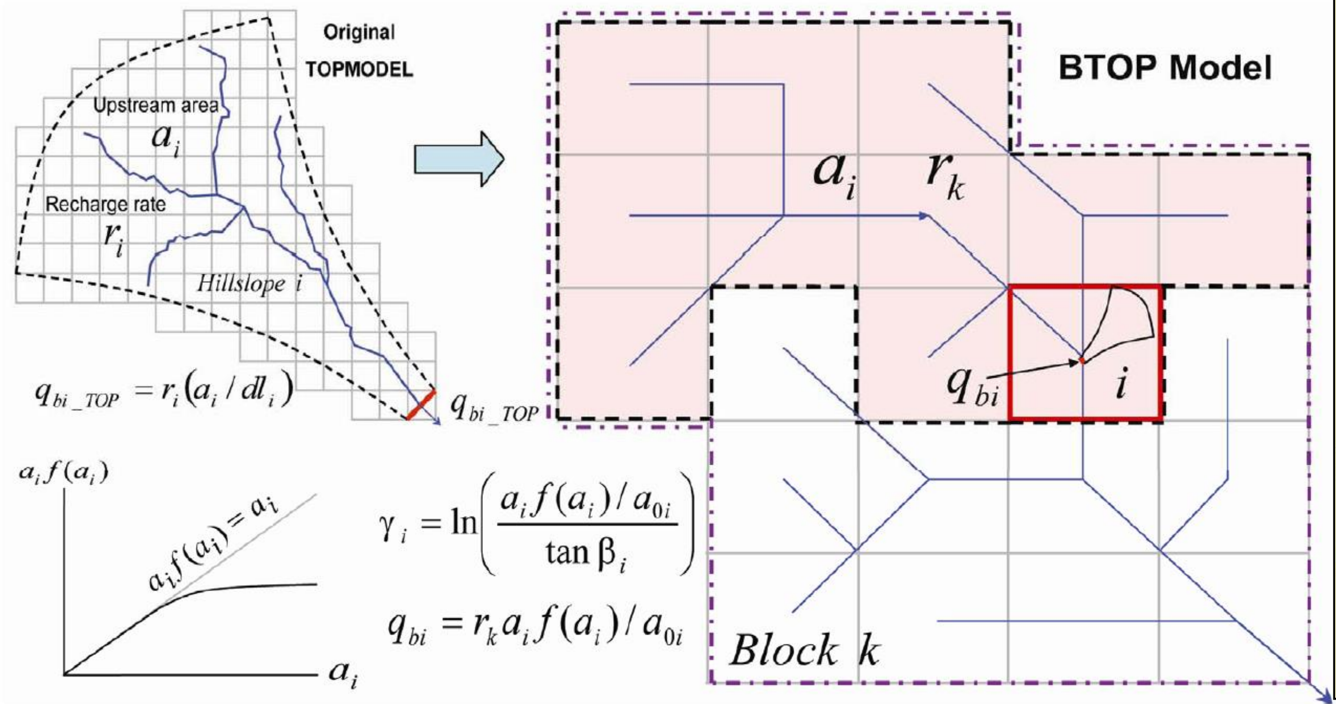
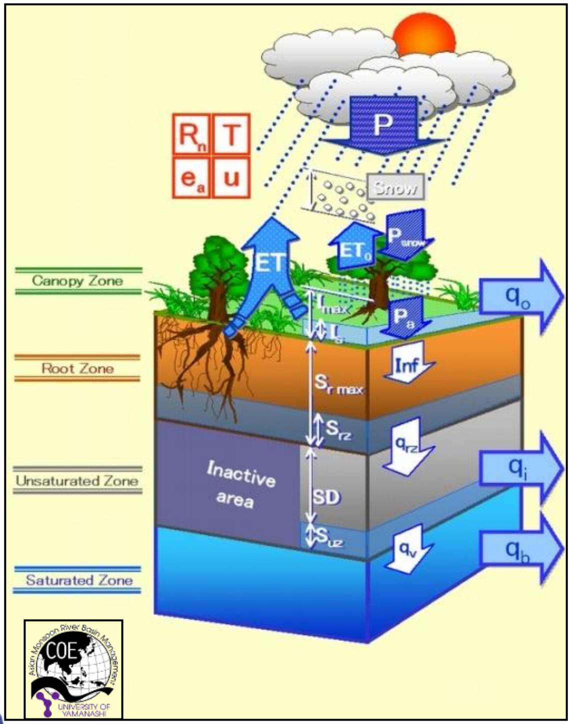
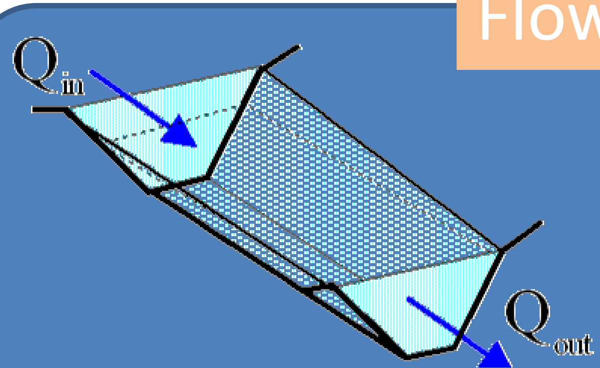
BTOP model

Runoff Generation





Flow Routing

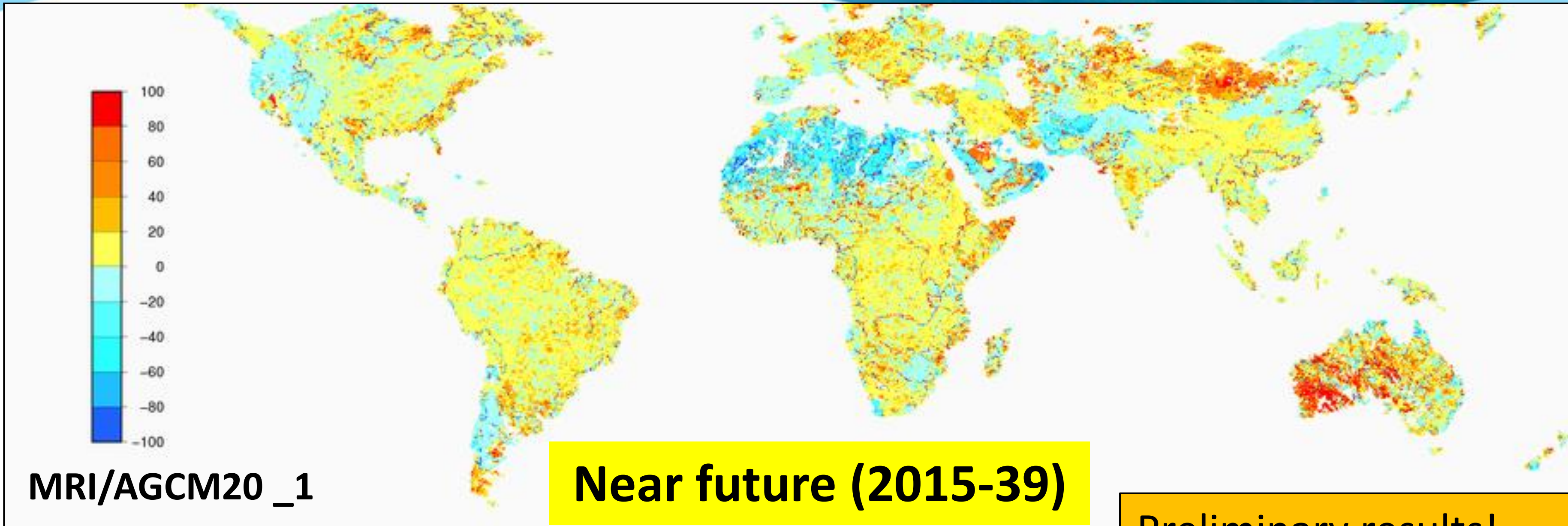


Muskingum-Cunge(M-C)
Modified M-C
Modified Manning Eq.

Takeuchi, Ao, Ishidaira, HSJ, 44(4), 1999
Takeuchi, Hapuarachchi, Zhou, Ishidaira, Magome, HP, 22, 2008

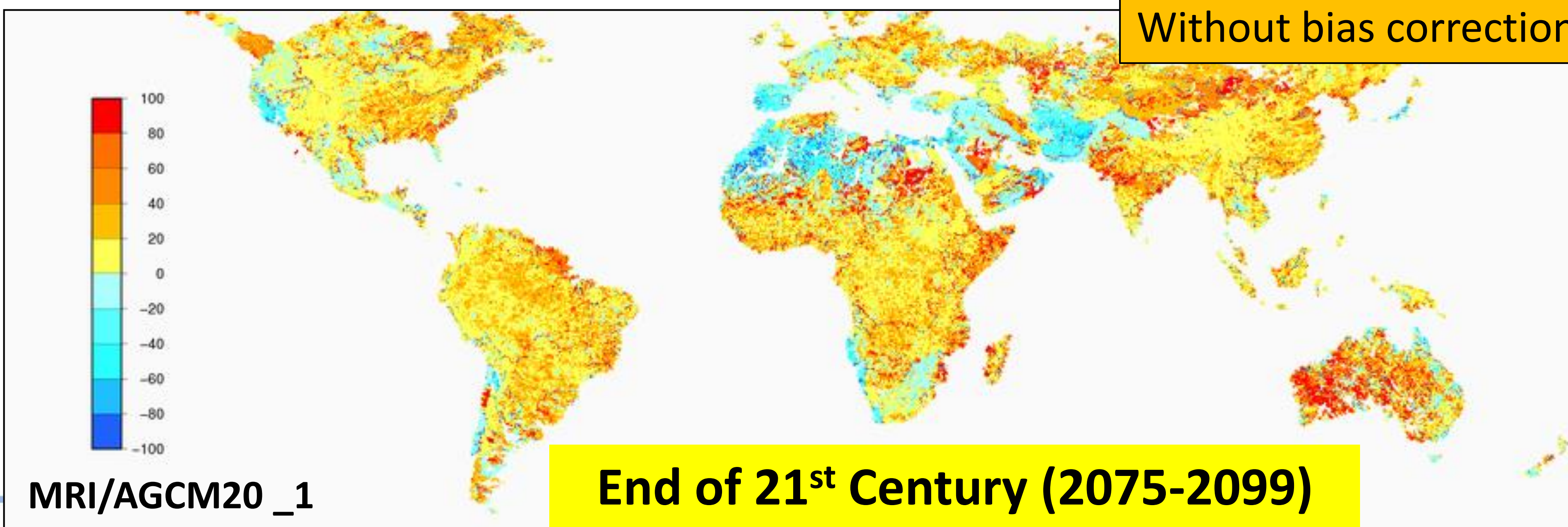
Takeuchi, Ishidaira, Sawada, Masumoto (eds) Studies of the MRB, HP, 22(9), 2008

50-year flood (annual max daily discharge): % increase from present



Near future (2015-39)

Preliminary results!
Without bias correction!



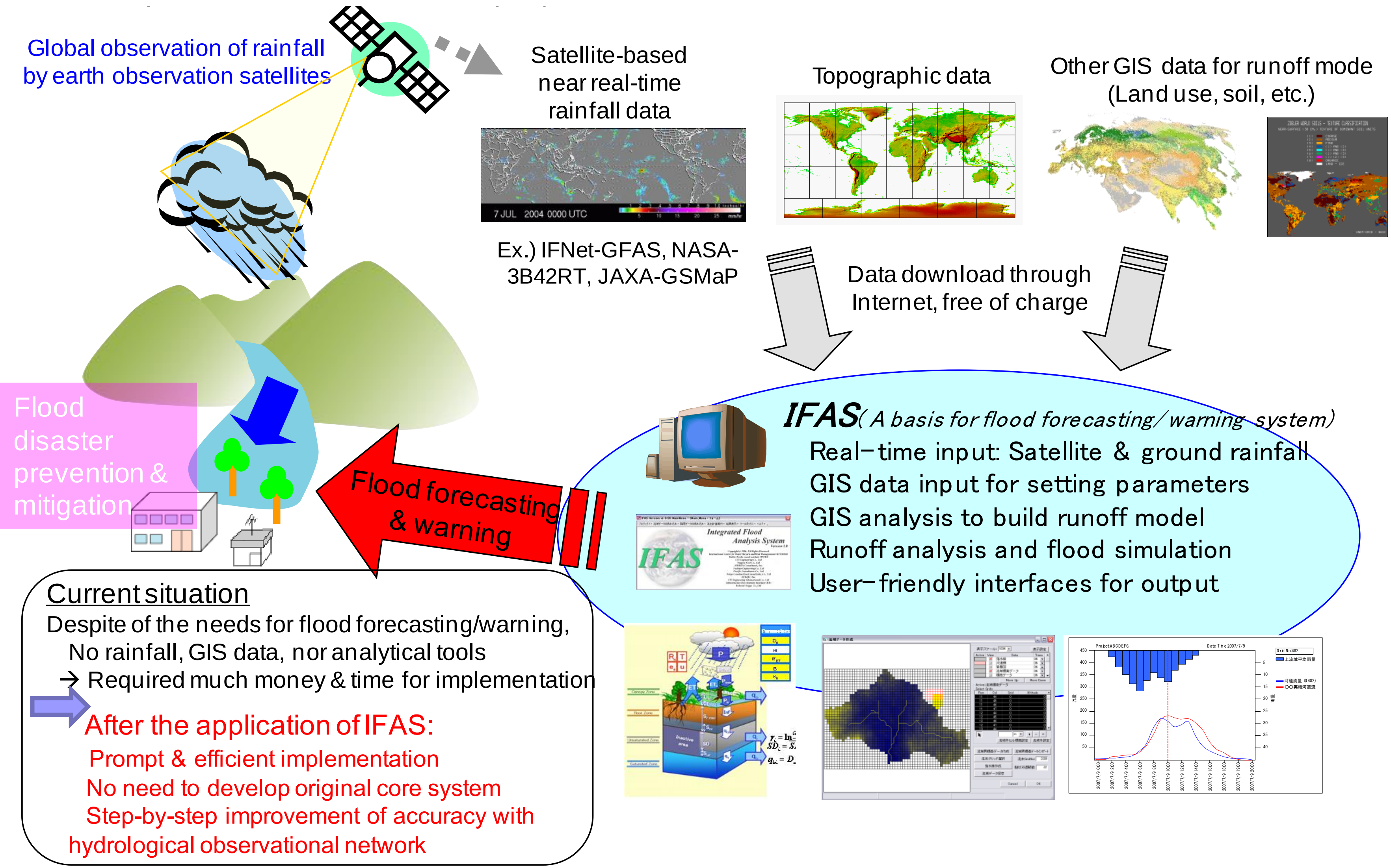
End of 21st Century (2075-2099)

2. Integrated Flood Analysis System (IFAS)

For the enbancement of the implementation of flood forecasting and warning system in poorly-gauged river basins, using not only ground-based but also global satellite-based rainfall data and global GIS data

Integrated Flood Analysis System IFAS

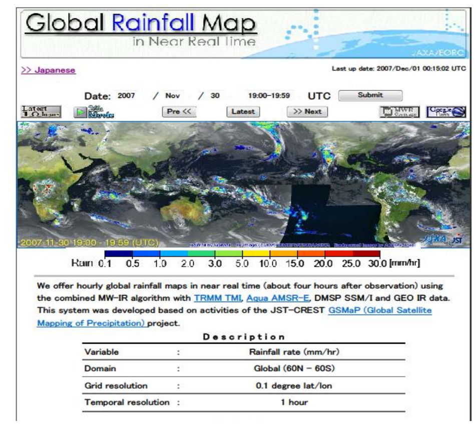
Toolkit to implement "Global Flood Alert System (GFAS) – Streamflow"



Satellite-based rainfall data

- There is no necessity for installation and maintenance of a rain gauge or transmission equipment .
  - Ground-based rainfall data are indispensable to get highly-accurate flood runoff analysis and forecast.
- Almost the worldwide coverage and a consistent accuracy is obtained.
- Resolution (time and space) and observation accuracy are low compared with properly-distributed ground-based rainfall data.

Product name	3B42RT	CMORPH	**GSMaP_NRT**
Developer and provider	NASA/GSFC	NOAA/CPC	JAXA/EORC
Coverage	N60° - S60°		
Resolution	0.25°	0.25°	**0.1°**
Resolution time	3 hours	3 hours	**1 hour**
Time lag	10 hours	15 hours	**4 hours**
Coordinate system	WGS		
Historical data	Dec 1997-	Dec 2002-	Dec. 2007～
Sensors	TRMM/TMI Aqua/AMSR-E AMSU-B DMSP/SSM/I IR	Aqua/AMSR-E AMSU-B DMSP/SSM/I TRMM/TMI IR	TRMM/TMI Aqua/AMSR-E ADEOS-Ⅱ/ AMSR SSM/I IR AMSU-B

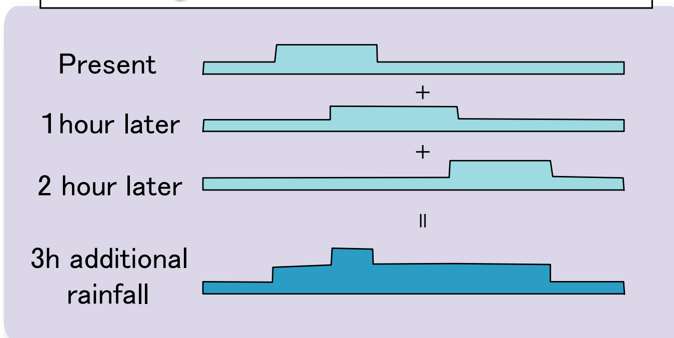


GSMaP_nRT

http://sharaku.eorc.jaxa.jp/GSMaP/index.htm

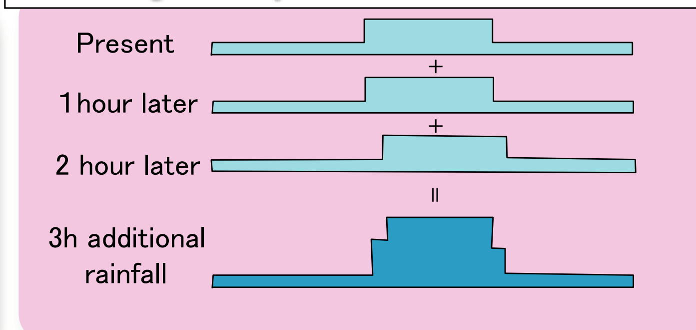
Algorithm for self-correction of satellite-based rainfall data without any ground-based rainfall data

Moving fast →Underestimation

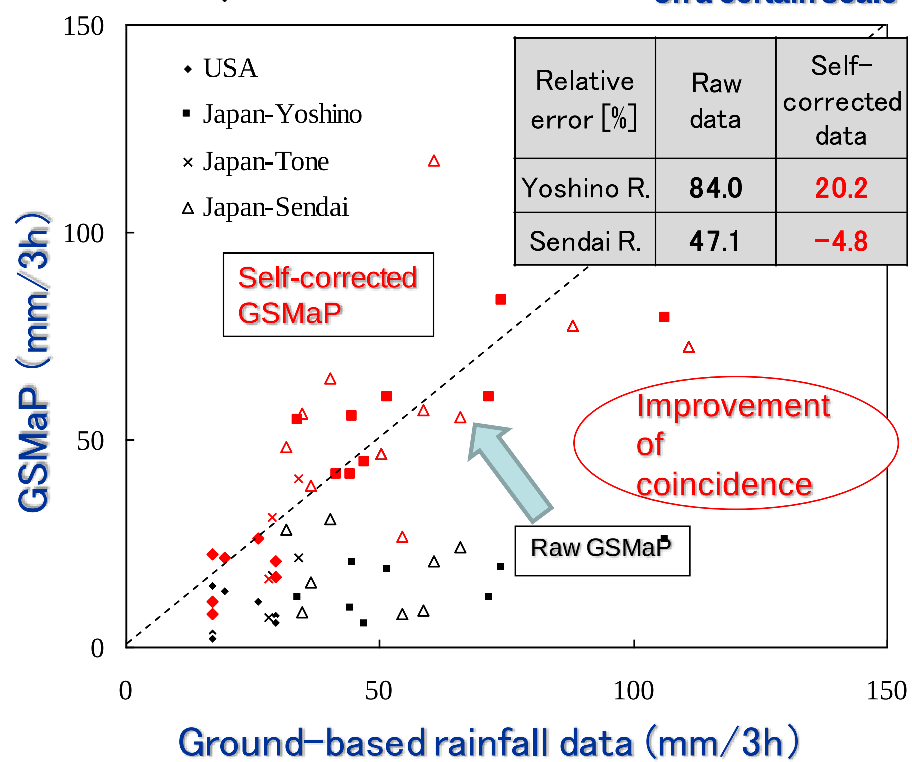


Small spatial variance of cumulative rainfall on a certain scale

Moving slowly → Better coincidence

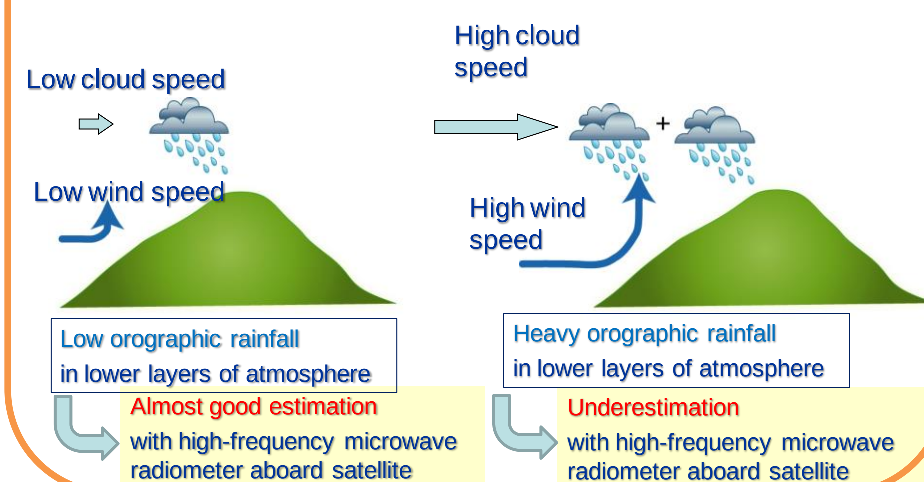


Large spatial variance of cumulative rainfall on a certain scale

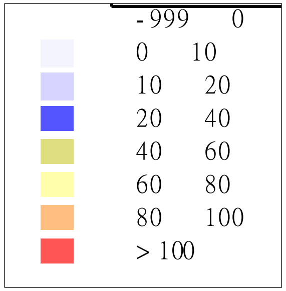


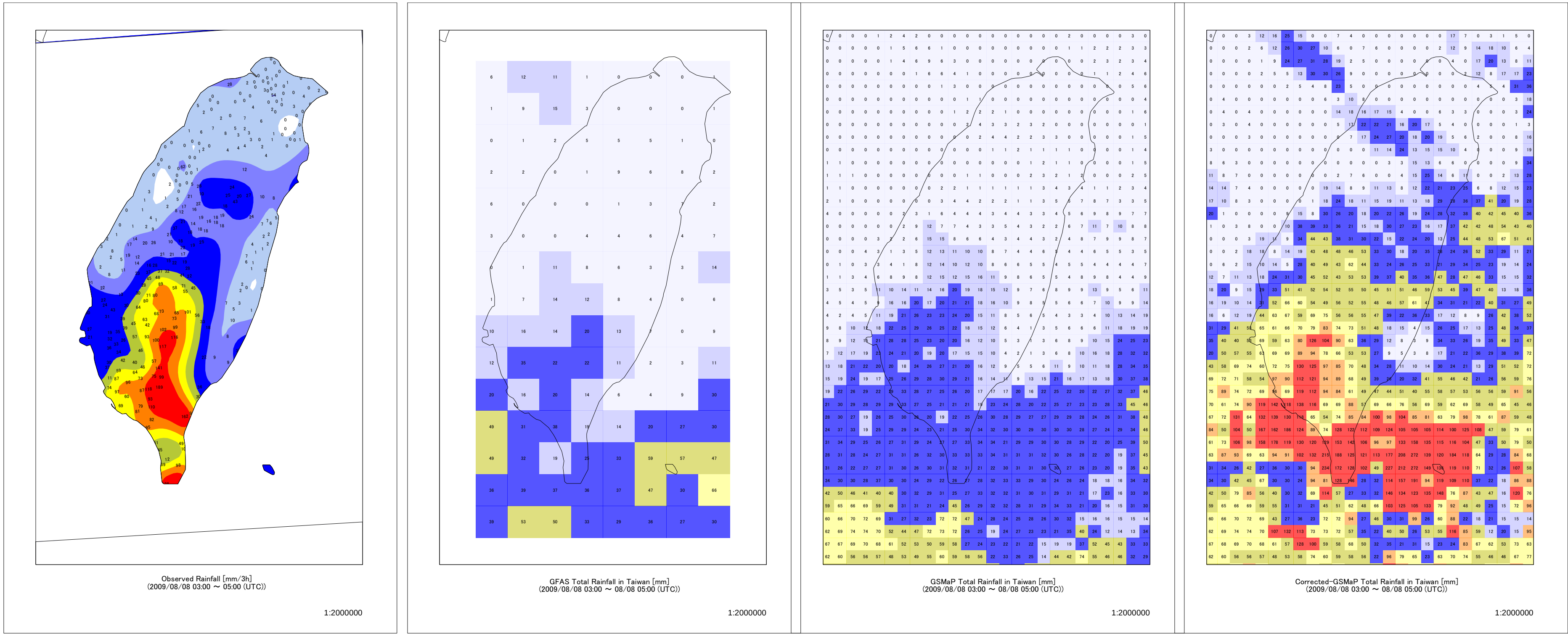
Relative error [%]	Raw data	Self-corrected data
Yoshino R.	84.0	20.2
Sendai R.	47.1	-4.8

A hypothesis on the reason why this self-correction is empirically effective.



Validation of self-correction method for JAXA-GSMaP (Typhoon Morakot, Taiwan, 2009)

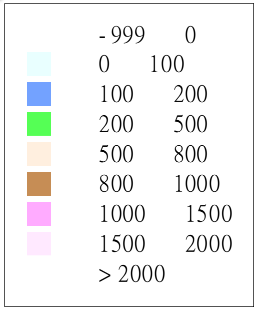


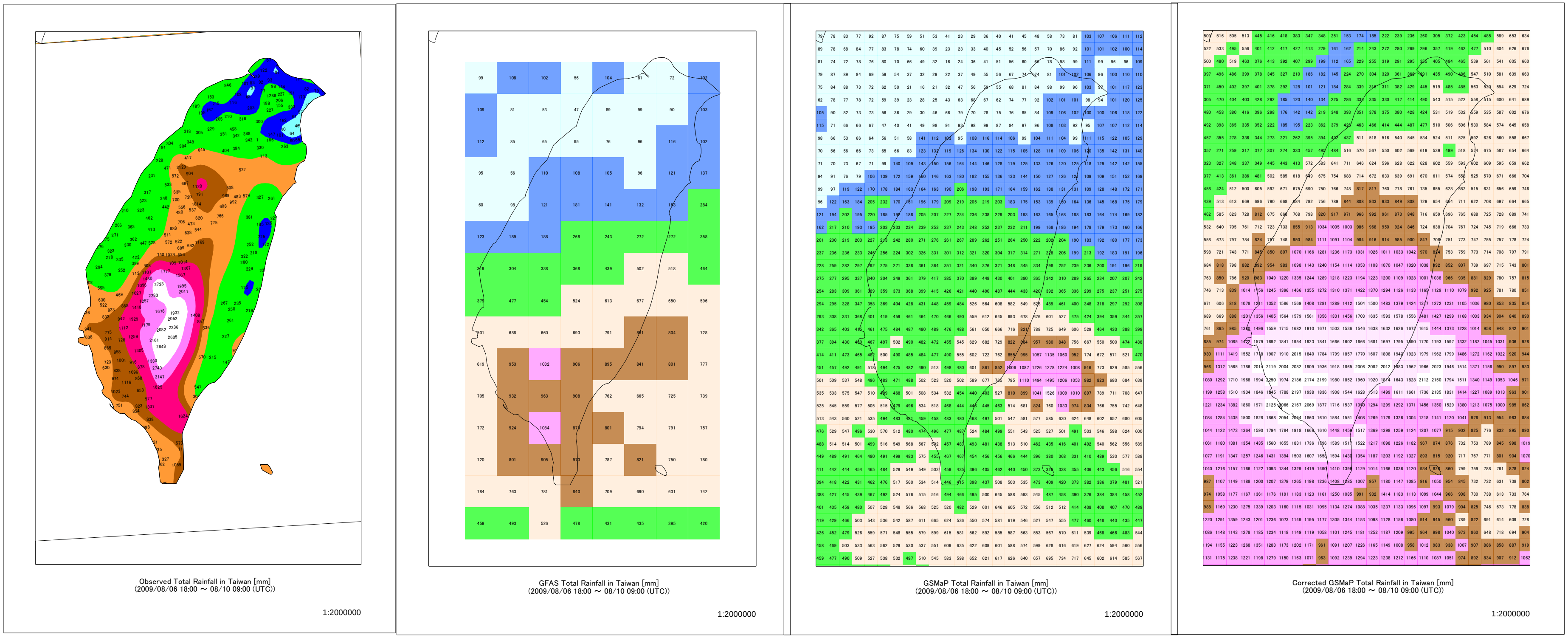


3 hour-rainfall (-2009/08/08 03:00 (UTC))

(**Left**: Ground gauged, **Center_L**: 3B42RT、**Center_R**: GSMaP、**Right**: Corrected GSMaP)

Validation of self-correction method for JAXA-GSMaP (Typhoon Morakot, Taiwan, 2009)

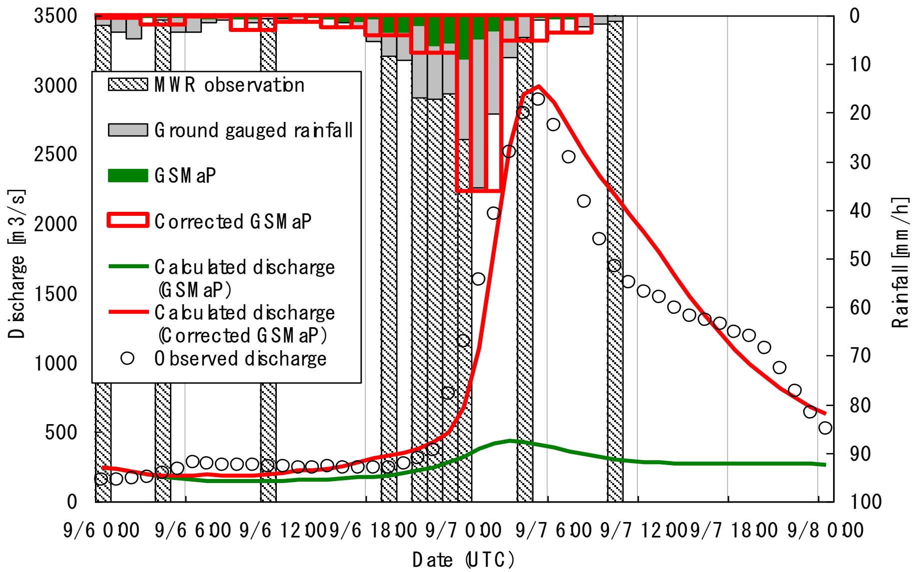




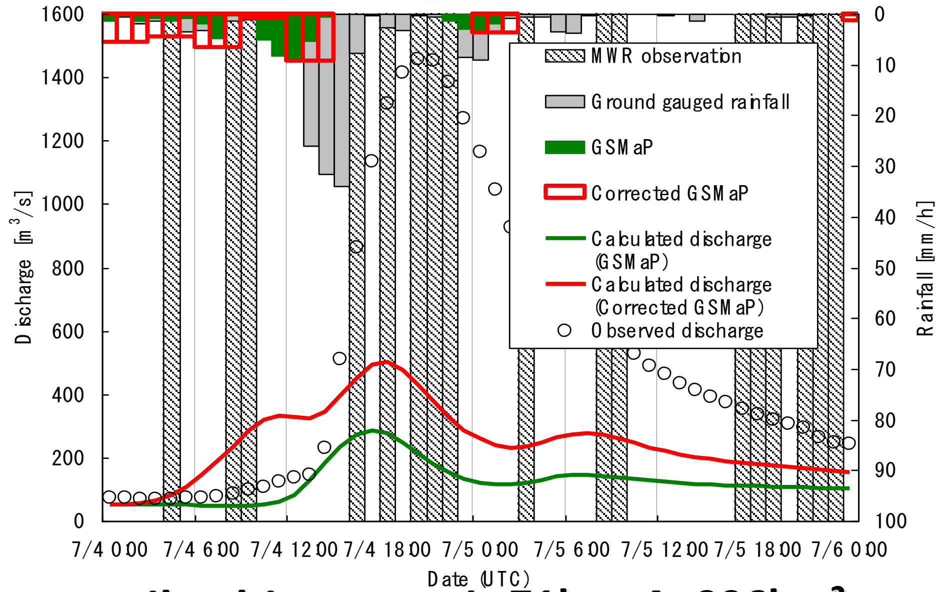
Total rainfall (2009/08/06 18:00 ～ 08/10 09:00) (UTC)

(**Left**: Ground gauged, **Center_L**: 3B42RT、**Center_R**: GSMaP、**Right**: Corrected GSMaP)

Comparison of calculation results



Sendaigawa **L=137km A=1,600km²**



Kikuchigawa **L=71km A=996km²**

In Kikuchigawa, discharge using corrected GSMaP underestimate due to accuracy of correction satellite-based rainfall.

	Product	Wave shape error E_W	Volume error E_V	Peak discharge error E_P
Sendaigawa	Ground-based	0.030	-0.021	0.030
	Satellite-based (corrected GSMaP)	0.029	-0.026	-0.035
Kikuchigawa	Ground-based	0.037	-0.027	0.015
	Satellite-based (corrected GSMaP)	0.342	0.425	0.656

Design concept of IFAS

1. To prepare interfaces to get satellite-based rainfall data in addition to ground-based rainfall data, to secure the worldwide availability of input data for flood forecasting/analysis system.

2. To adopt two types of distributed-parameter hydrologic models, the parameters of which can be estimated as the first approximation based on globally-available GIS databases to secure the worldwide availability of hydrologic models for flood forecasting/analysis.

3. To implement GIS analysis modules in the system to set up the parameters for the flood forecasting/analysis model, therefore no need to depend on external GIS softwares.

5. To prepare a series of easy-to-understand graphical user interfaces for data input, modeling, runoff-analysis, and displaying the outputs.

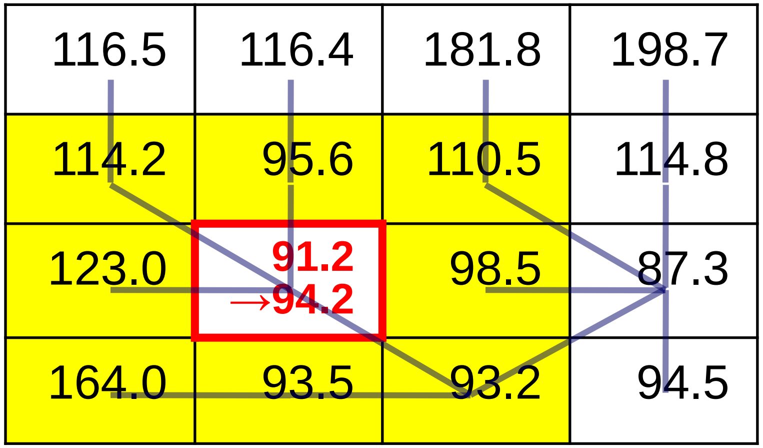
6. To distribute the executable program, free of charge, from the ICHARM/PWRI website

Flood runoff simulation model creation using global GIS data

Import data

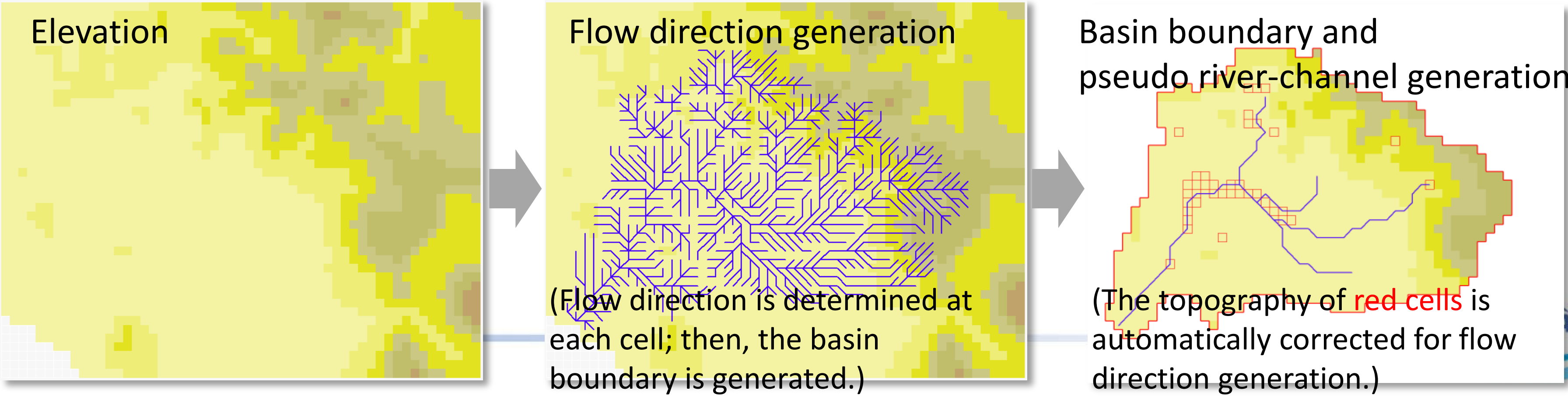
Type	Product	Provider
Elevation	Global Map(Elevation data)	ISCGM
	GTOPO30	USGS
	Hydro1k	USGS
Land use	GLCC	USGS
	Global Map(Land cover)	ISCGM
	Global Map(Land use)	ISCGM
Geology	Geology	CGWM
Soil type	Soil Texture	UNEP
	Soil Water Holding Capacity	UNEP
	Soil Depth	GES

Example of elevation data of a each cell and a river channel network



Modify elevation until all sells are decided their flow directions

Creation of River channel network and basin shape based on elevation data

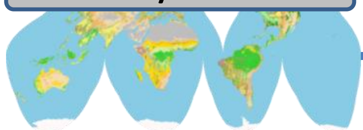


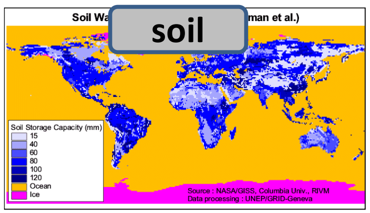
Parameter estimation using GIS data

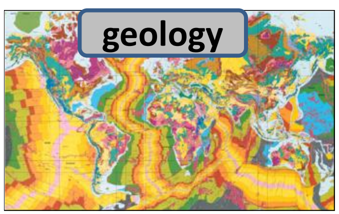
[surface
groundwater

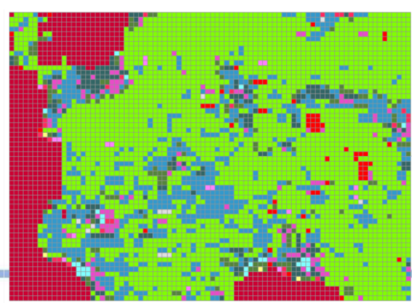
1. Import GIS data → 2. Distribute GIS data into some classes → 3. Input value for each tank → 4. Set value for each cell

GIS data



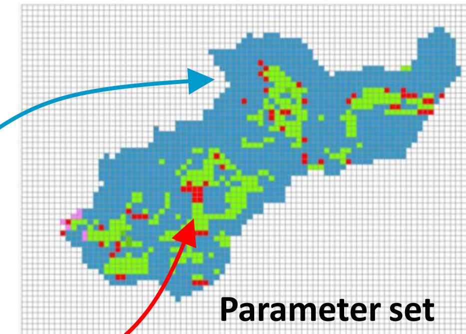






Imported GIS data

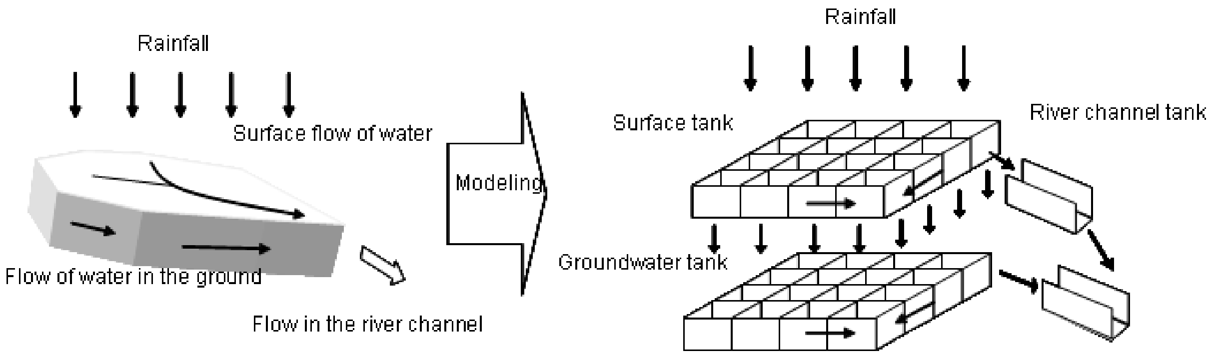
Land use classification (GlobalMap)	Surface parameter	Infiltration capacity	Rough -ness	○○
Broadleaf Evergreen Forest	1	0.0005	0.7	…
Broadleaf Deciduous Forest				
Needleleaf Evergreen Forest				
Needleleaf Deciduous Forest				
Mixed Forest				
Tree Open				
Shrub	2	0.00002	2	…
Herbaceous				
Herbaceous with Sparse Tree/Shrub				
Sparse vegetation				
Bare area (gravel, rock)				
Bare area (sand)				
Cropland	3	0.00001	2	…
Paddy field				
Cropland / Other Vegetation Mosaic				
Mangrove				
Wetland				
Urban	4	0.000001	0.1	…
Snow, ice	5	0.00001	2	…
Water bodies				

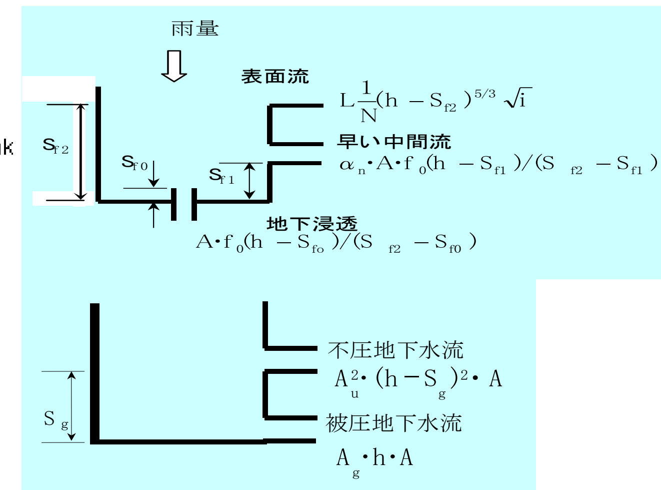


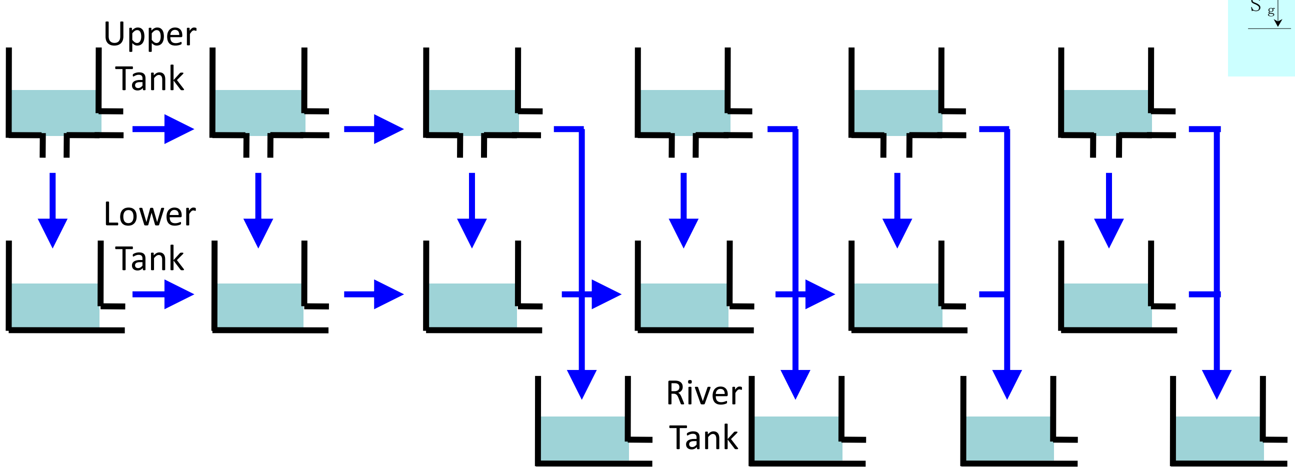
- ◆IFAS has already set default parameter.
- ◆Each parameter reflects local condition.

Default runoff analysis models

- Two types of distributed hydrological model
  - PWRI Distributed Hydrological Model (PDHM Ver.2)(below)
  - BTOP Model (coming soon!)

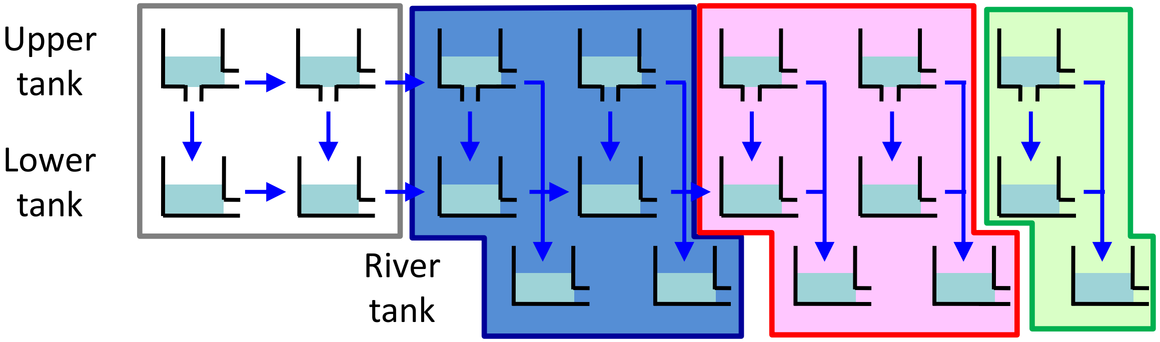


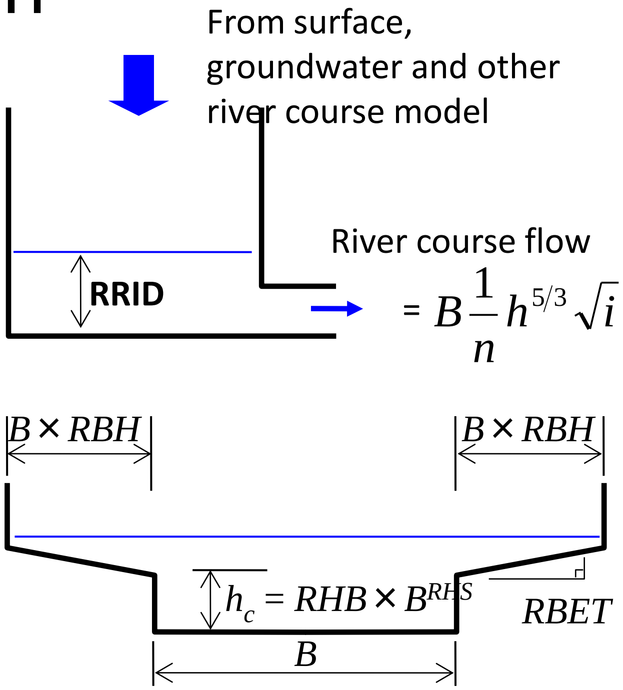




Upper area → Lower area

River course model parameter estimation using Cell type classification

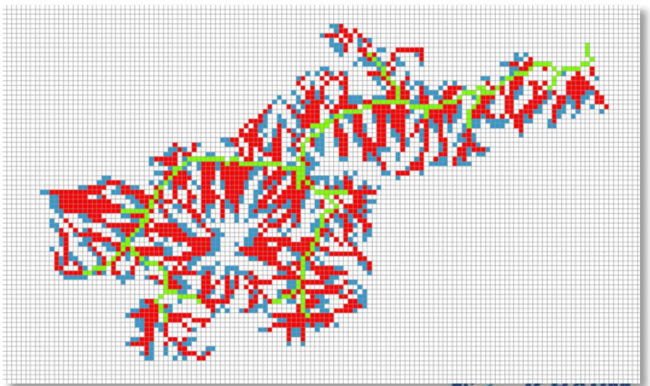




Upper area → Lower area

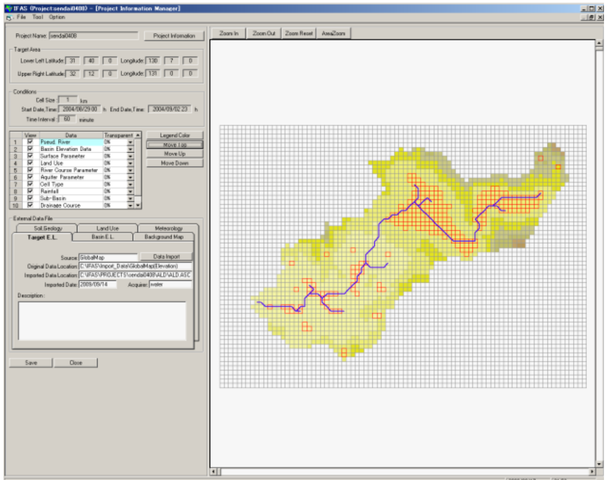
	Cell type 0	Cell type 1	Cell type 2	Cell type 3
Number of upper cell (default)	1～2	3～4	5～64	65～
Constant of Resume law	-	6	7	8
Manning roughness coefficient	-	0.07	0.05	0.035
･･･	-	･･･	･･･	･･･

Cell type3 routing by the Kinematic waving method.
(displayed as a main river channel)

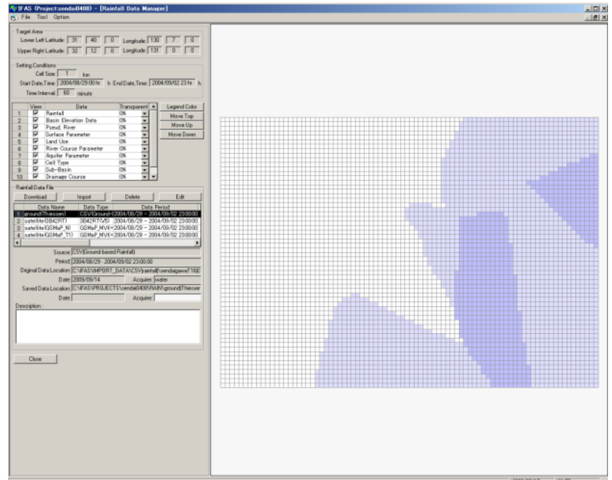


Interface display

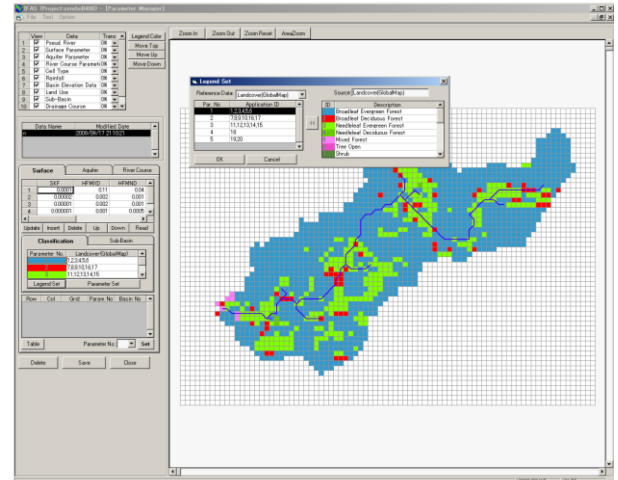
Main display



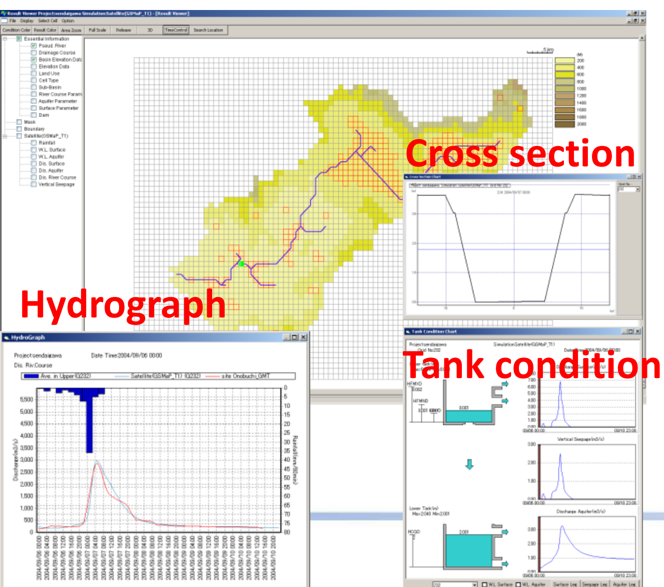
Edit display of rainfall data



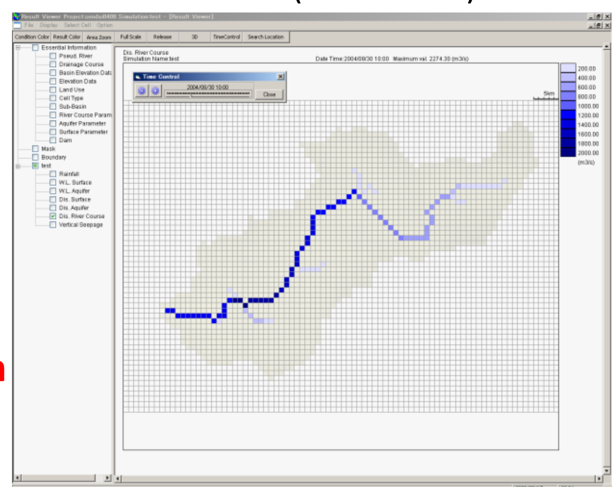
Setting display of parameter



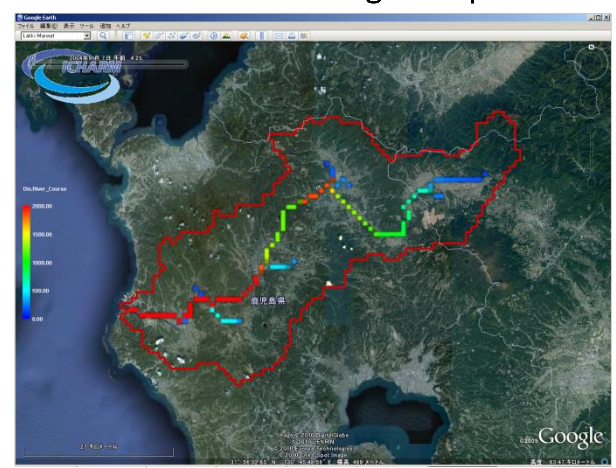
Calculation result



Calculation (Plane view)

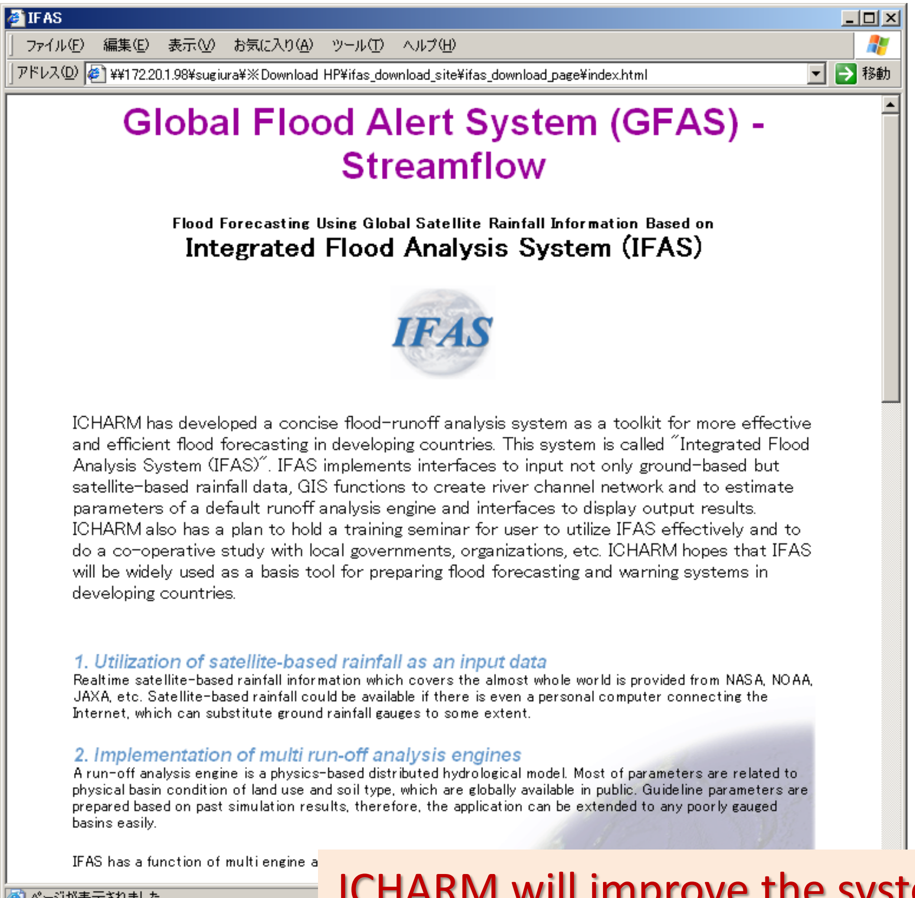


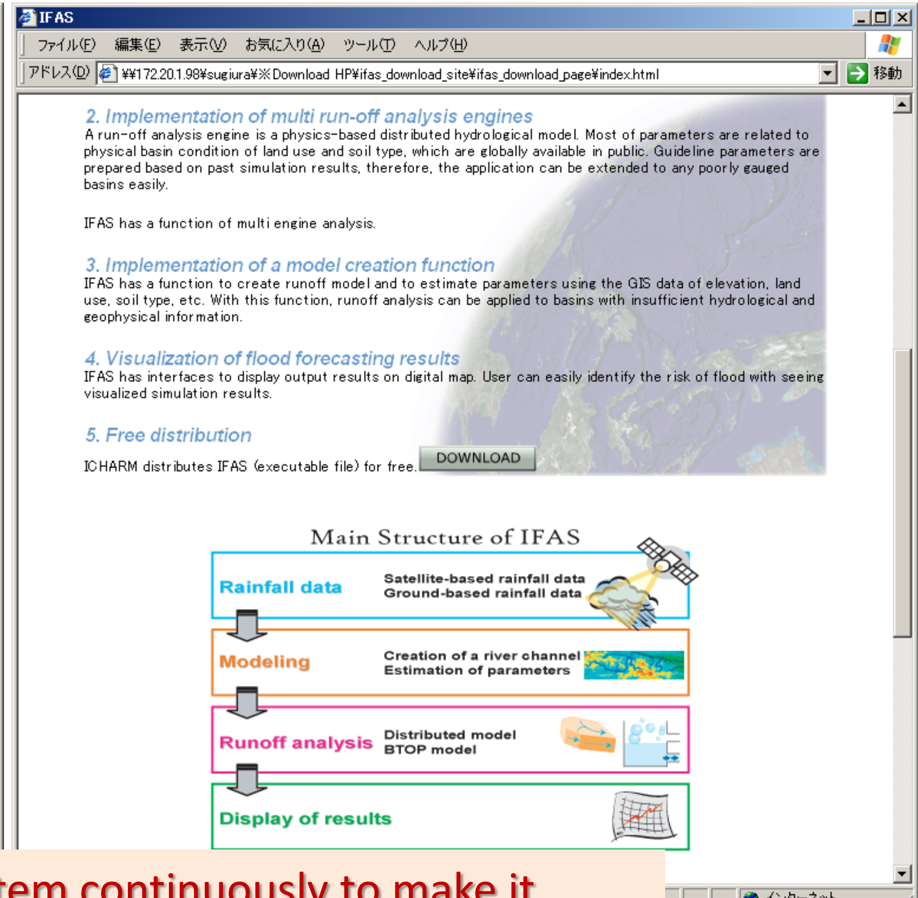
Plane view on Google Map



ICHARM Website to download IFAS (only IFAS-PDHM as of 2010/10)

http://www.icharm.pwri.go.jp/index.html





ICHARM will improve the system continuously to make it more user-friendly software and contribute to flood mitigation at local communities.

Future plan of IFAS Development and Dissemination activity

ⅰ)ICHARM will implement (or improve) hydrologic runoff analysis engine in IFAS to make long-term runoff calculations.

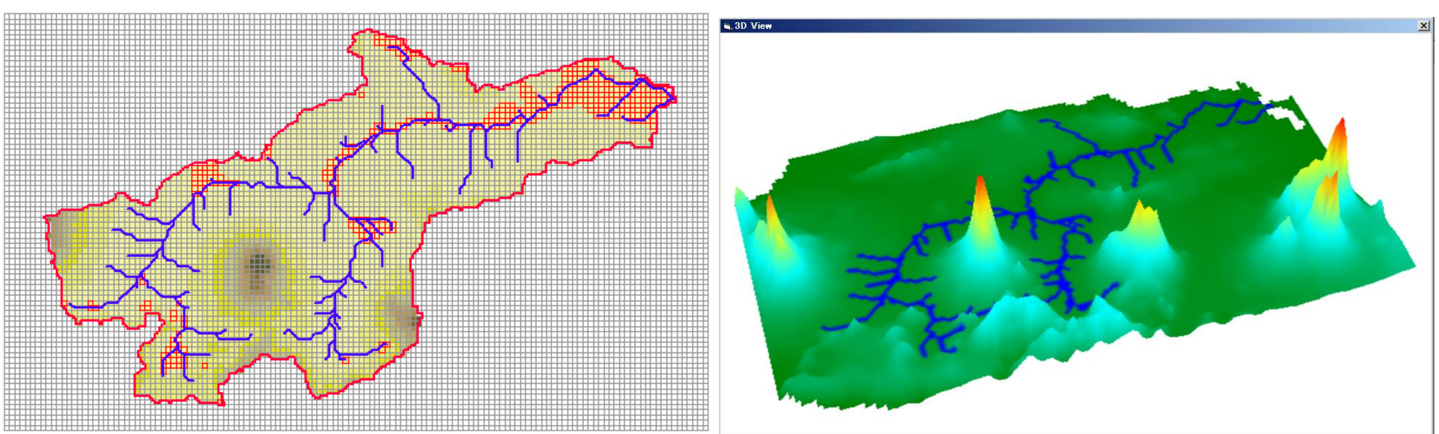
ⅱ)ICHARM will implement hydraulic flood flow calculation system under the tidal effect along coastal areas.

ⅲ) Development of a methodology to further improve the accuracy of global satellite-based rainfall data with/without ground-based data, and its validation for flood forecasting on a river basin scale.

ⅳ) IFAS will be upgraded by adding more functions and libraries

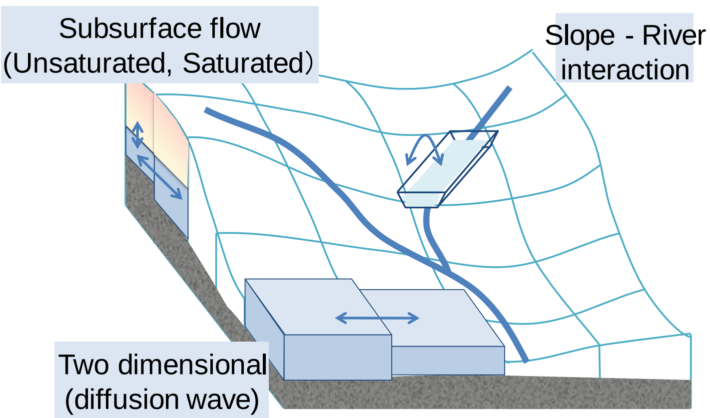
ⅴ) ICHARM provide early warning system for evacuation from flood and inundation based on IFAS in Bengawan Solo river basin, Indonesia.

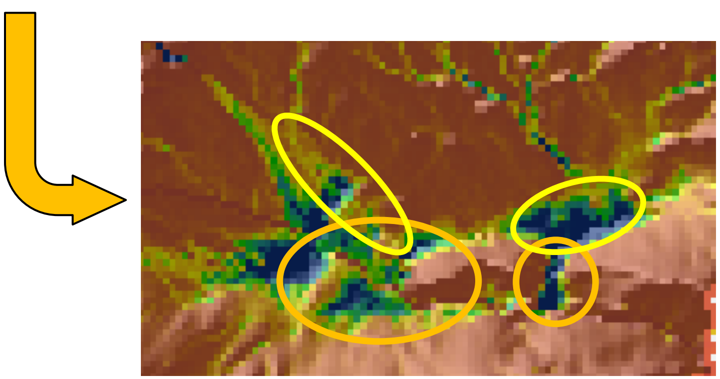
ⅵ) The implementation of flood forecasting/warning systems should be promoted through technical training activities provided by ICHARM.



Current situation of creating Bengawan Solo river basin model by IFAS

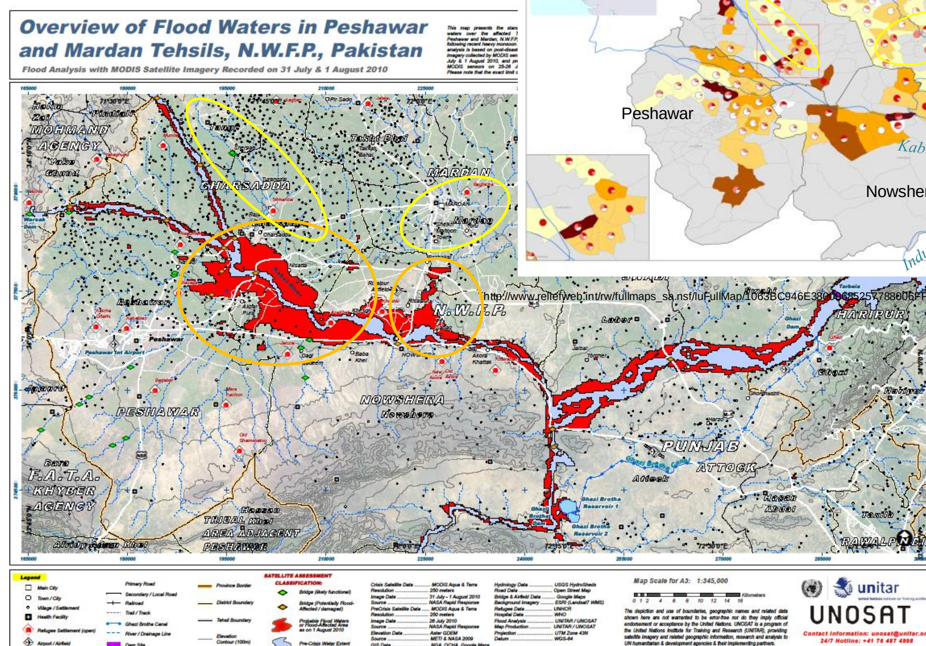
Comparison between satellite-based inundation extent and inundation simulations with a ICHARM's Rainfall-Runoff-Inundation (RRI) Model (under development) for Pakistan flood, August 2010

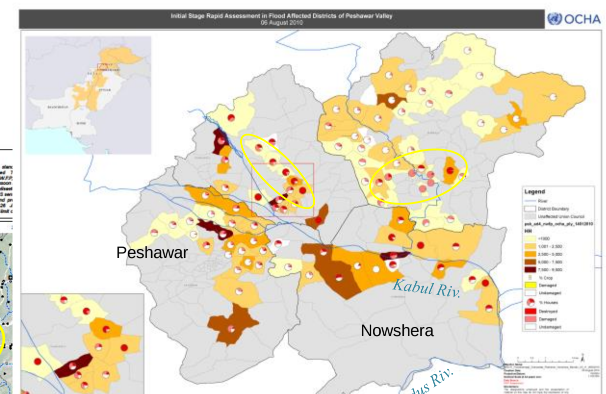




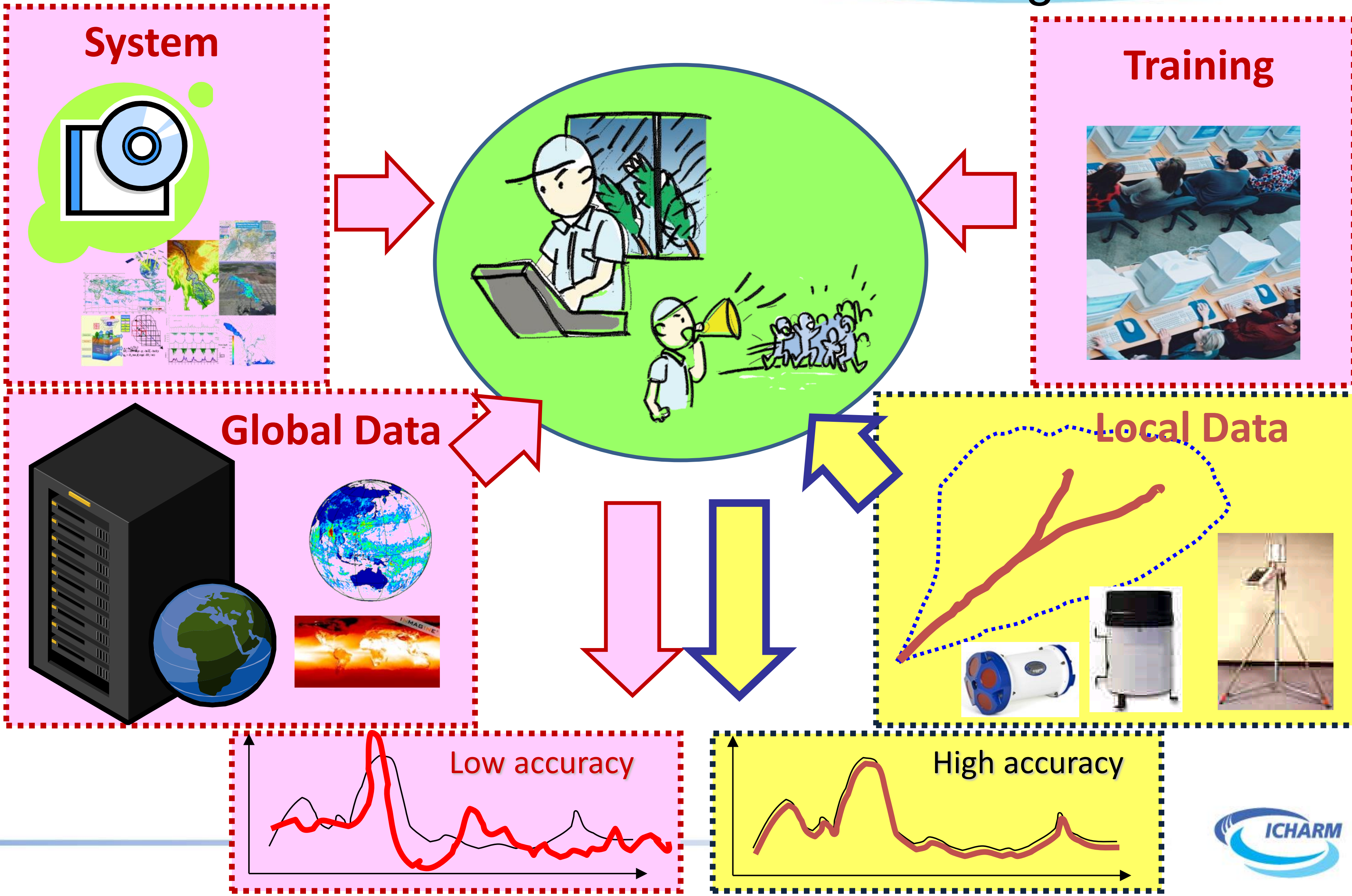
Sayama et al.(2010)

Runoff-inundation simulation can **interpolate missing satellite-based information** on flood inundation area caused by flash flood.





IFAS to enhance local ownership of flood forecasts & in-situ observation network on the ground



ICHARM

Summary

- A simple statistical bias-correction method, “Hybrid Quantile Bias-Correction Method”, for daily rainfall simulated by GCM was developed and verified, through the intercomparison of extreme rainfall data with ground-based database and flood runoff analysis. This method secures both the good agreement of extreme rainfall events and the seasonal pattern of overall rainfall characteristics. This method is expected to be useful in making climate-change impact analysis on hydrology, water resources and water-related disaster risk.
- A user-friendly common base for flood runoff analysis, “Integrated Flood Analysis System (IFAS)”, was developed. This software tool is expected to be useful in quick & efficient implementation of flood runoff analysis system anywhere in the world, especially in poorly-gauged river basins .

ICHARM