Capabilities of Data Integration and Prediction

- Some implications to the GEOSS-AWCI Next Stage -

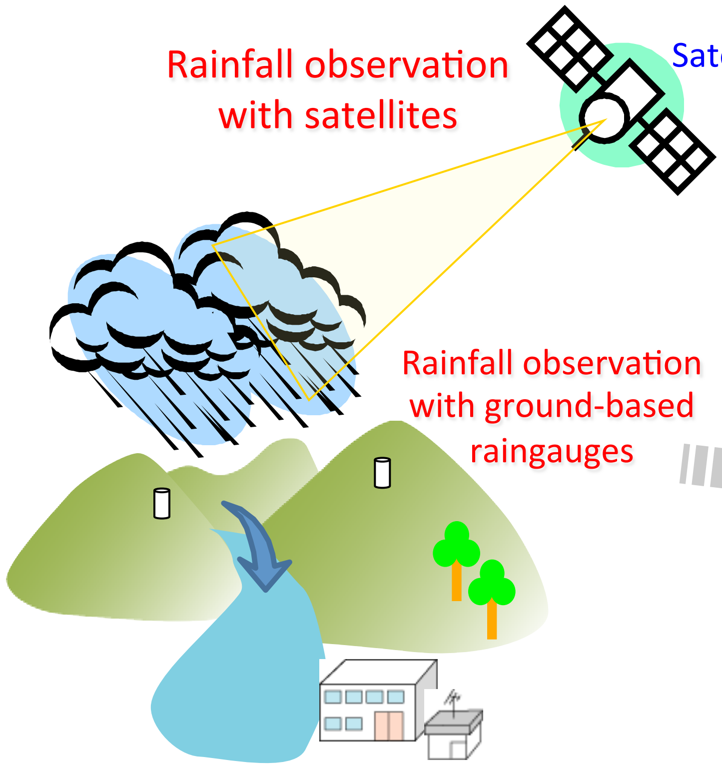
Kazuhiko FUKAMI

International Centre for Water Hazard and Risk Management under the auspices of UNESCO (UNESCO-ICHARM),
Public Works Research Institute (PWRI), Japan

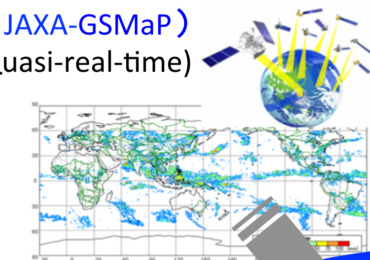
Integrated Flood Analysis System (IFAS)

Flood runoff analysis system with satellite-based rainfall & global GIS information

Rainfall observation with satellites

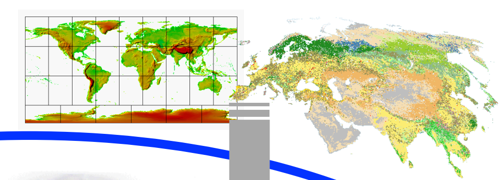


Satellite-based rainfall data
（JAXA-GSMaP）
(Quasi-real-time)



Courtesy of JAXA

GIS information on basin characteristics
(Elevation, Land use, Geology)
Available on internet



Rainfall observation with ground-based raingauges

User friendly display

- Input of ground-based and satellite-based rainfall with the original self-correction algorithm
- Easy creation of distributed-parameter runoff model with global/local GIS
- Implementation of necessary GIS tools and GUI interfaces on IFAS

Flood runoff (flow & water level) analysis

Flood forecasting / warning
→ Safe evacuation

Towards reduction/ prevention of flood disasters

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Main features of IFAS:

Not only ground-based but also satellite-based rainfall data area applicable

Distributed-parameter flood runoff model creation using global GIS data

With limited historical / real-time hydrological databases in poorly-gauged rivers

All-in-one package for GIS data analyses

Free download for the executable program from ICHARM-IFAS website
http://www.icharm.pwri.go.jp/index.html

Prompt and efficient implementation of flood analysis and forecasting system even in poorly-gauged rivers
and
step-by-step improvement of accuracy
with the **enhancement of in-situ hydrological observational network**

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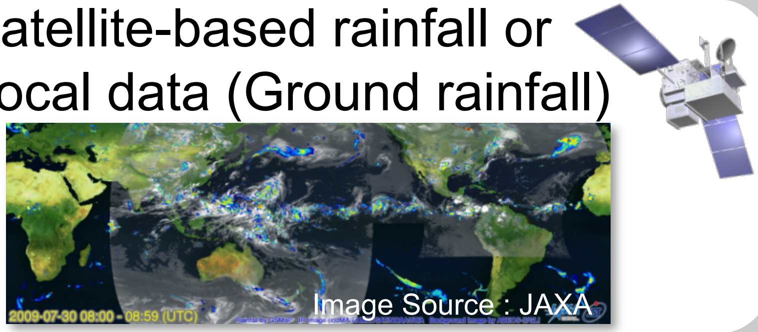
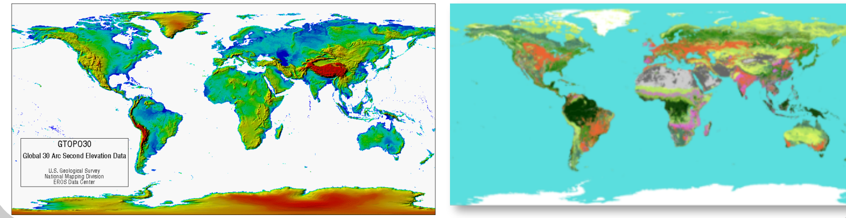
Outline of IFAS

Satellite-based rainfall or
Local data (Ground rainfall)

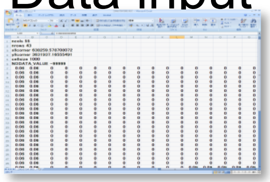


Global GIS datasets
Elevation data, Land use data, etc.

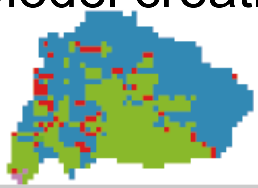


IFAS (Integrated Flood Analysis System)

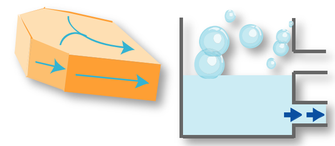
Data input



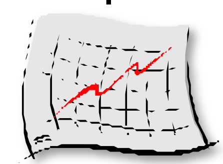
Model creation



Run-off analysis

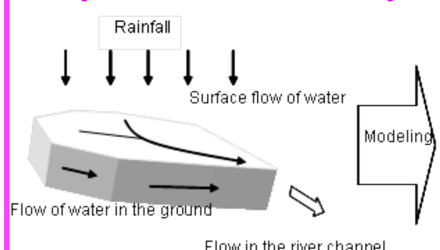


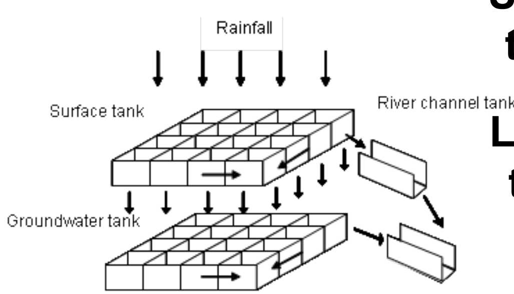
Output



Calculation of river discharge

Runoff Analysis Engine : PWRI Distributed hydrological model (PDHM Ver.2)

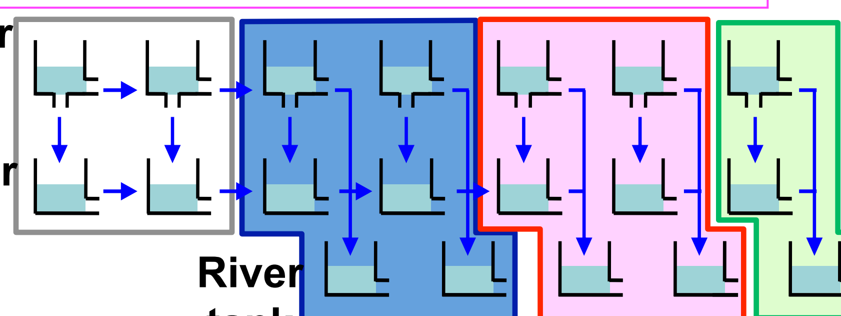




Upper tank

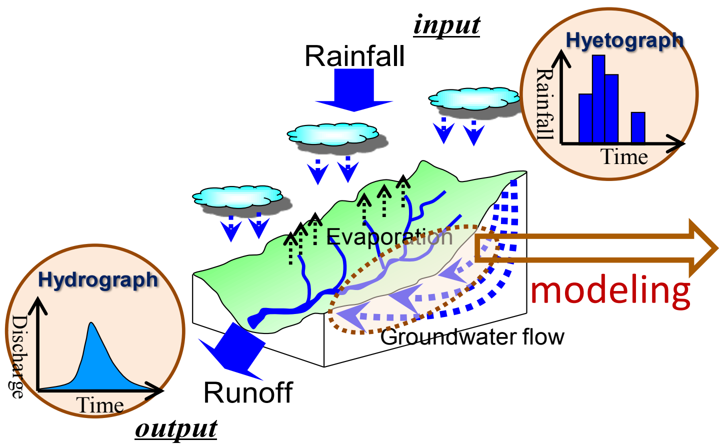
Lower tank

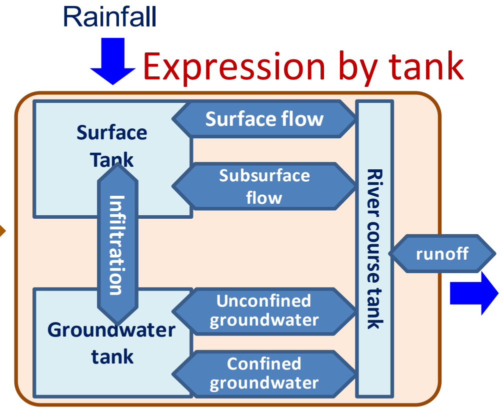
River tank

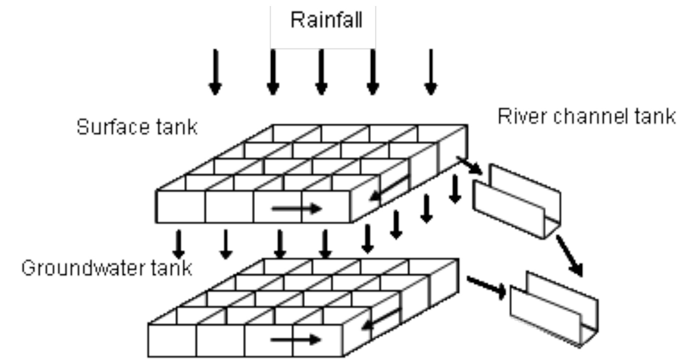


Upper area → Lower

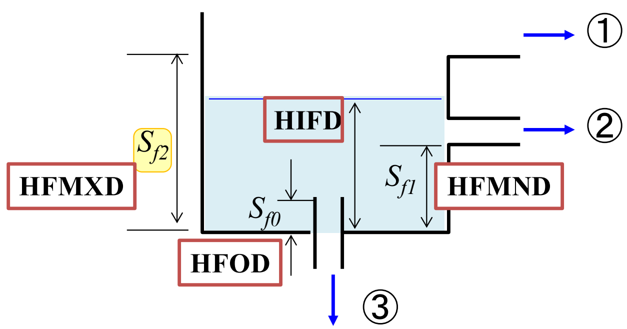
Runoff Analysis Model on IFAS (PDHM Ver.2)







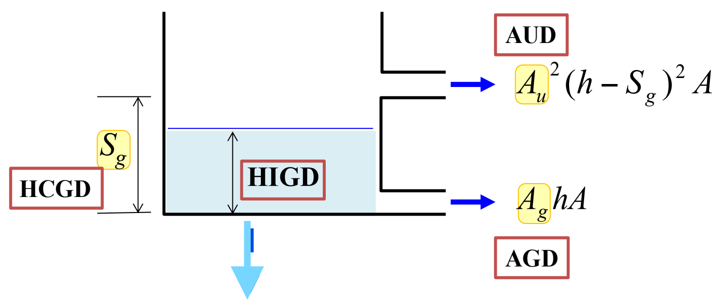
Surface Tank (Upper tank)	Groundwater Tank (Lower tank)	River Course Tank



①Surface flow: $L\frac{1}{N}(h-S_{f_2})^{\frac{5}{3}}\sqrt{i}$ SNF

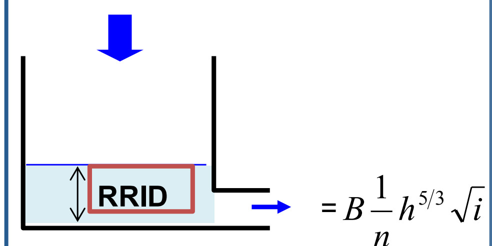
②Subsurface flow: $\alpha_n A f_0(h-S_{f_1})/(S_{f_2}-S_{f_1})$ FALFX

③Infiltration: $Af_0(h-S_{f_0})/(S_{f_2}-S_{f_0})$ SKF



It is possible to set α as groundwater loss.

Parameters of upper tank varies by land cover
(forest, bush and meadow, cropland



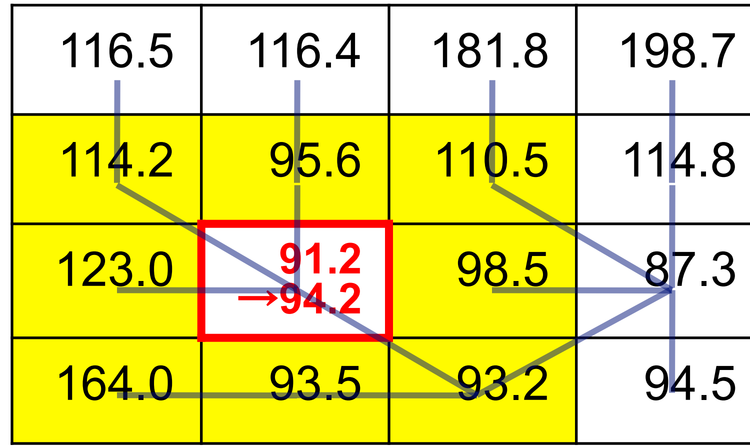
Even if you have no cross-section data of river channels, it is possible to calculate flood flow in steep river channels through the Manning Formula with the assumption or wide rectangular channels.

Flood runoff simulation model creation using global GIS data

Import data

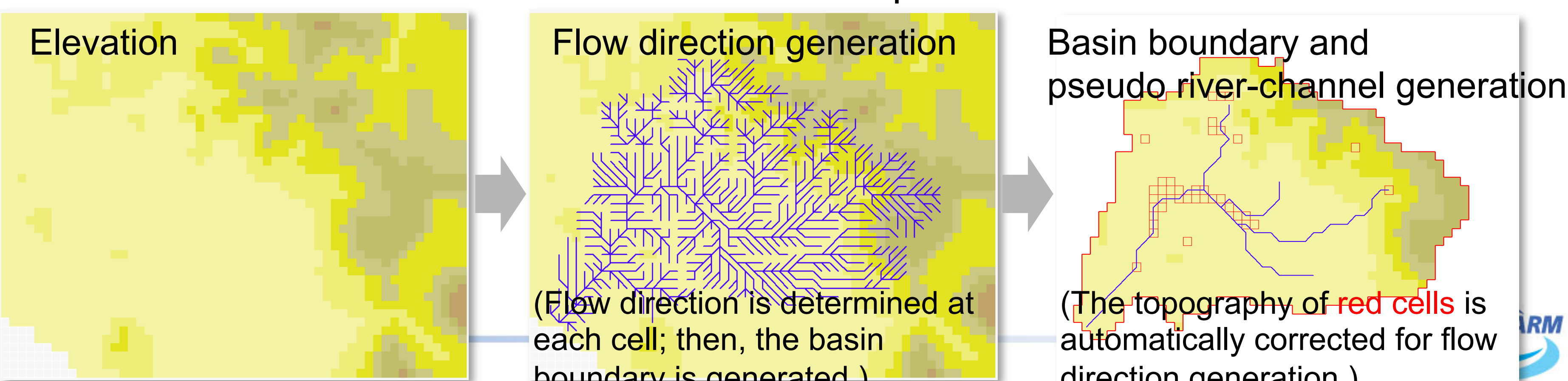
Type	Product	Provider
Elevation	Global Map(Elevation data)	ISCGM
	GTOPO30	USGS
	Hydro1k	USGS
Land use	GLCC	USGS
	Global Map(Land cover)	ISCGM
	Global Map(Land use)	ISCGM
Geology	Geology	CGWM
Soil type	Soil Texture	UNEP
	Soil Water Holding Capacity	UNEP
	Soil Depth	GES

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

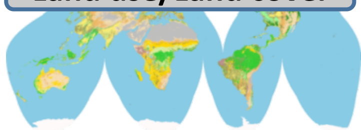


Parameter estimation using GIS data [surface / groundwater]

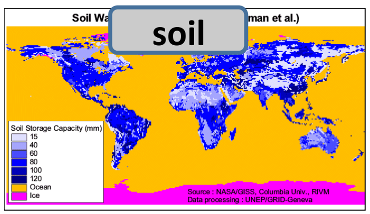
1. Import GIS data → 2. Distribute GIS data into some classes → 3. Input value for each tank → 4. Set value for each cell

GIS data

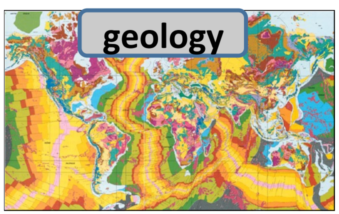
Land use/Land cover

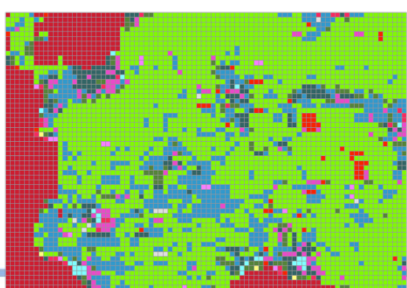


soil



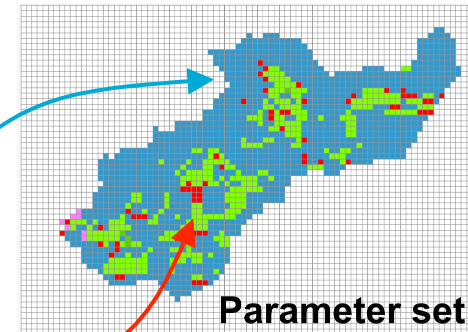
geology





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				

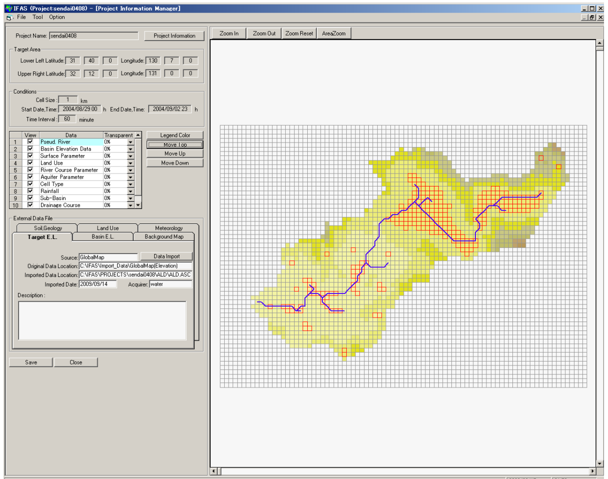


Parameter set

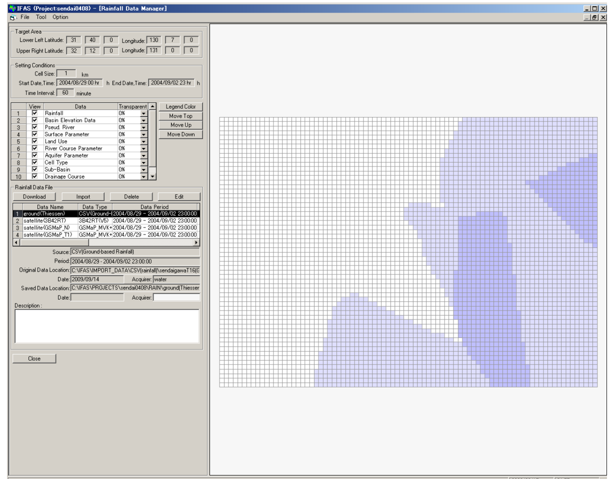
- ◆IFAS has already set default parameter.
- ◆Each parameter reflects local condition.

Interface display

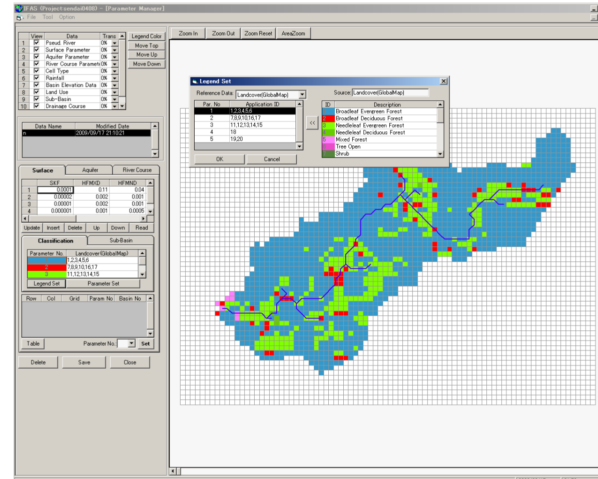
Main display



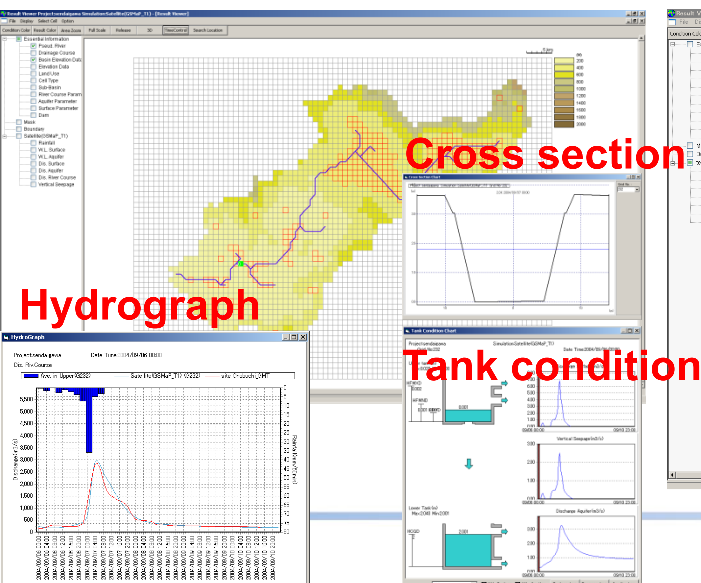
Edit display of rainfall data



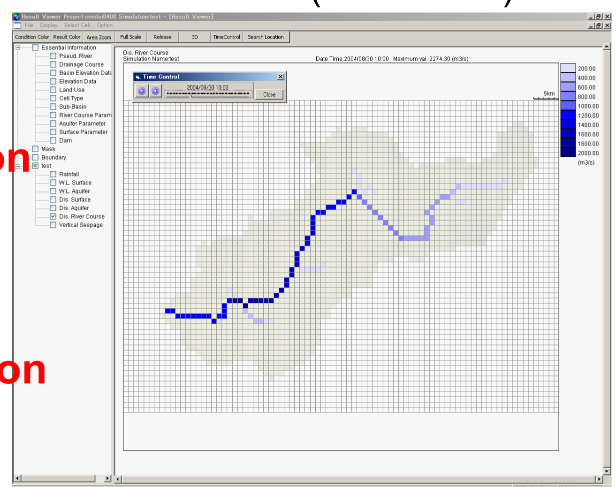
Setting display of parameter



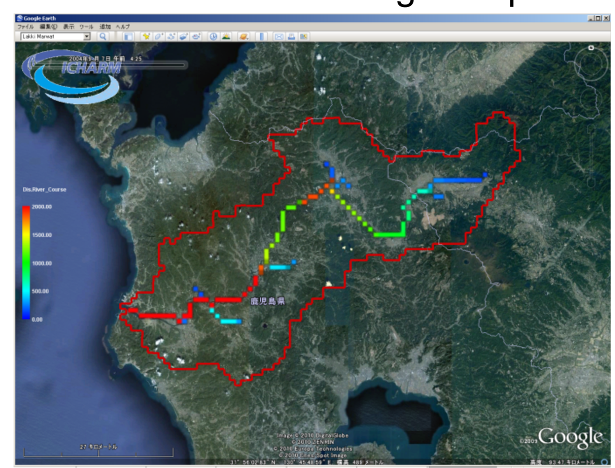
Calculation result



Calculation (Plane view)

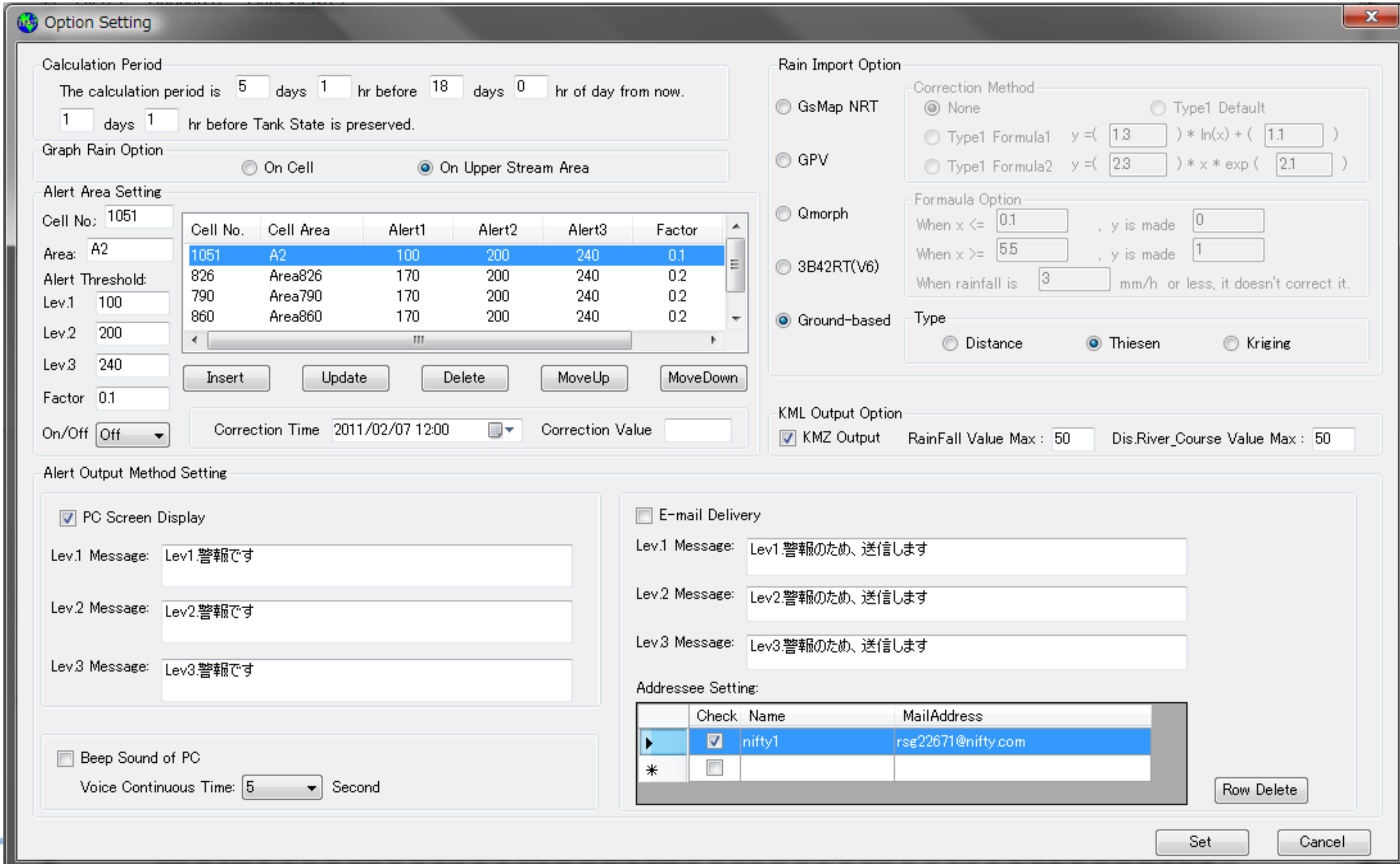


Plane view on Google Map



New IFAS-extra-module for Automatic Warning System (IFAS Ver.1.3)

(automatic incremental simulation for each time step and alert window & e-mail)



IFAS Training workshops (2008 – 2011)

- Purpose of the training course

  To build capacities to undertake hydrological analyses/forecasting in relatively ungauged basins through coupled usage of global / insitu data.

Program

•Remote Sensing of Precipitation from Space (JAXA)
•Introduction of river administration in Japan
•Introduction of Global Flood Alert System
•Operating procedures for IFAS
•Validation method of satellite-based rainfall
•Current conditions and problems in each country

- International Workshop on Application and Validation of GFAS

2008: Ethiopia, Zambia, Cuba, Argentina, Bangladesh, Guatemala, Nepal (7countries)

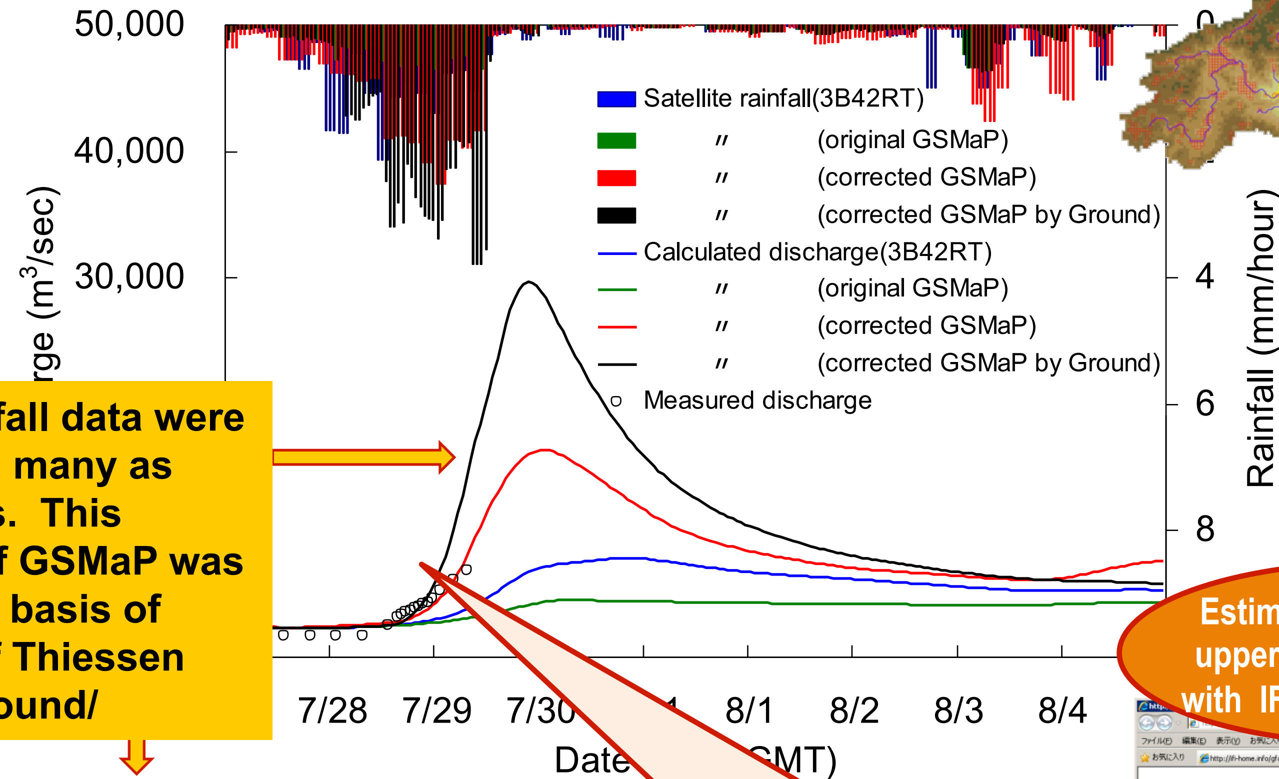
2009: India, Indonesia, Viet Nam, Bangladesh, Nepal, Laos (6countries)

- IFAS Seminars in overseas (sponsored by ADB, JAXA, UNESCAP, etc.)

Nepal (2009), Indonesia, Myanmar, Vietnam (2010),
Pakistan, Thailand, and India (2011)

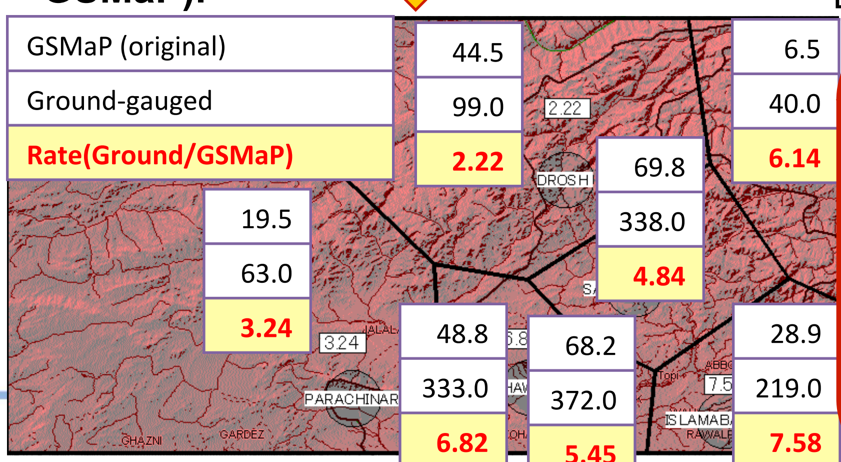
- ICHARM PhD & Master Courses, JICA short courses, etc.

IFAS-based runoff analysis: Kabul River, Pakistan

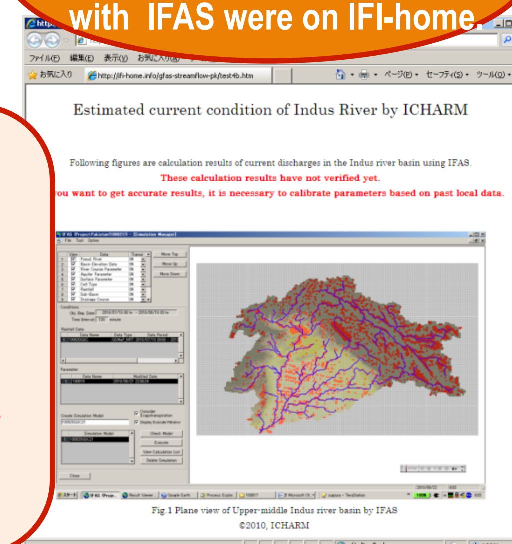


Calculated by Default parameter

Ground rainfall data were 2~7 times as many as GSMaP ones. This correction of GSMaP was made on the basis of each ratio of Thiessen polygon (Ground/ GSMaP).



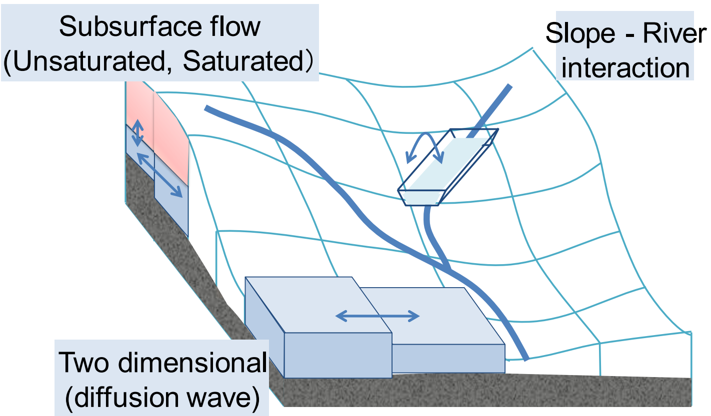
Estimated hydrographs in upper & middle Indus river with IFAS were on IFI-home.

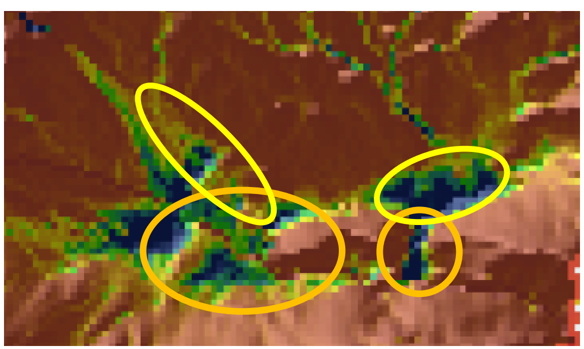


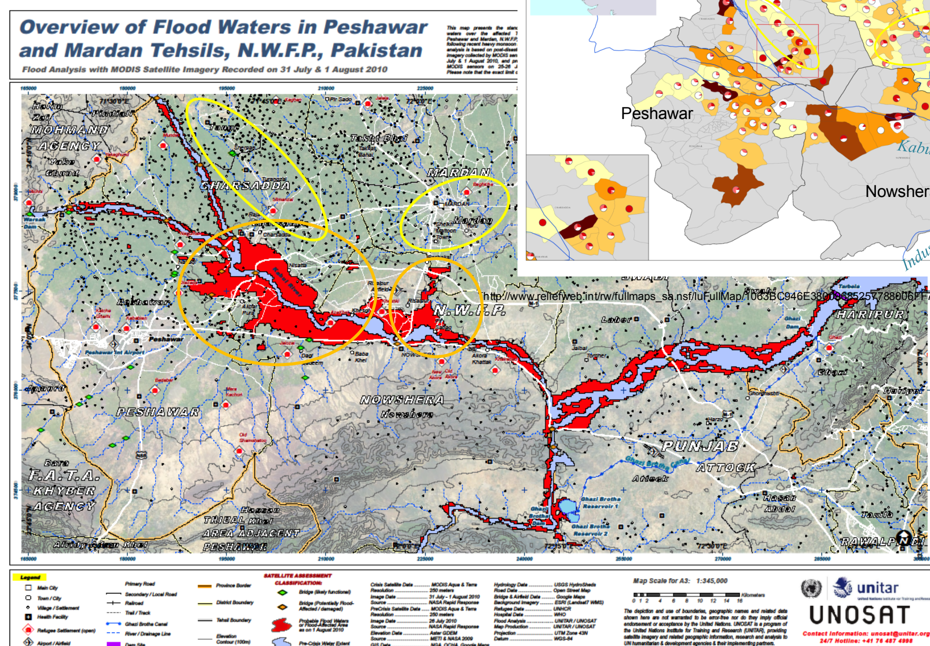
Alghouth the runoff simulation with ICHARM's self-correction algorithm without any ground-based rainfall data seemed best, this does not necessarily mean the truth. In any case, this shows the high potential of satellite-based runoff simulation.

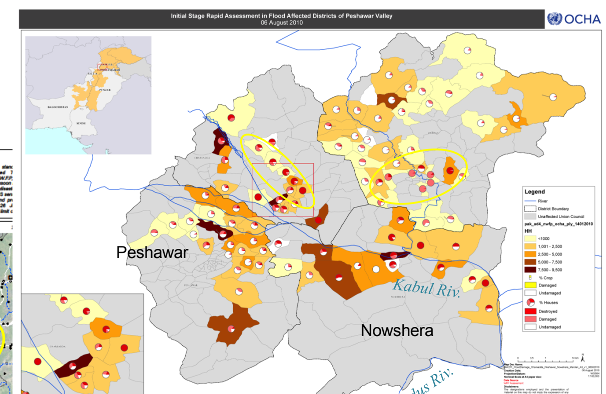
Comparison between satellite-based inundation extent and inundation simulations with another ICHARM's Rainfall-Runoff-Inundation (RRI) Model for Pakistan flood, August 2010

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







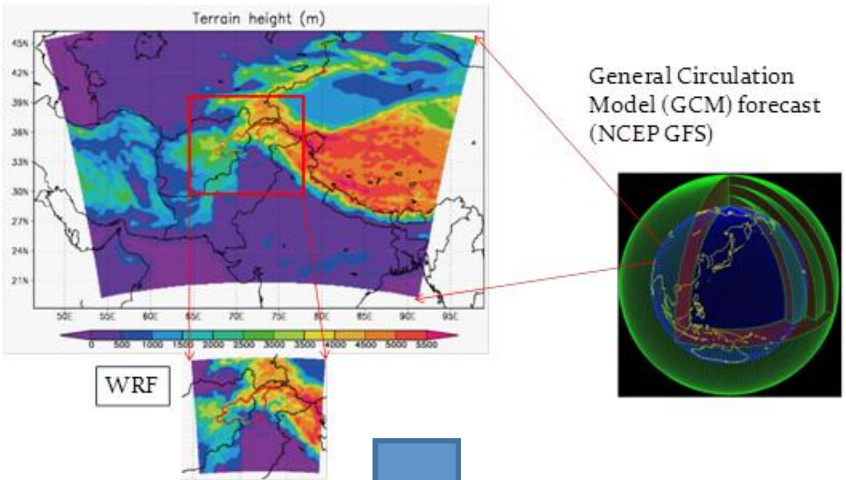


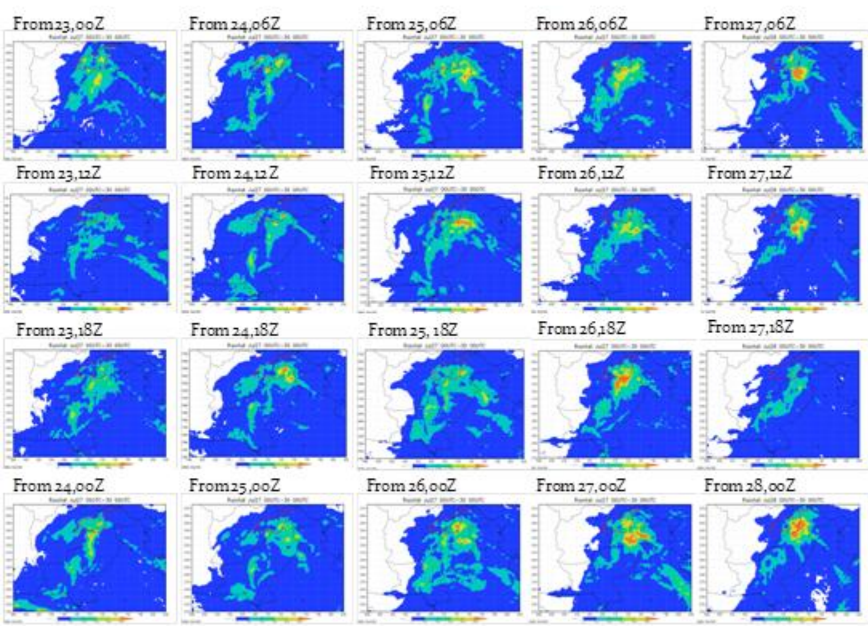
http://www.reliefweb.int/rw/fullmaps_sa.nsf/luFullMap/1063BC946E380BC852577880061F75B/$File/map.pdf?OpenElement

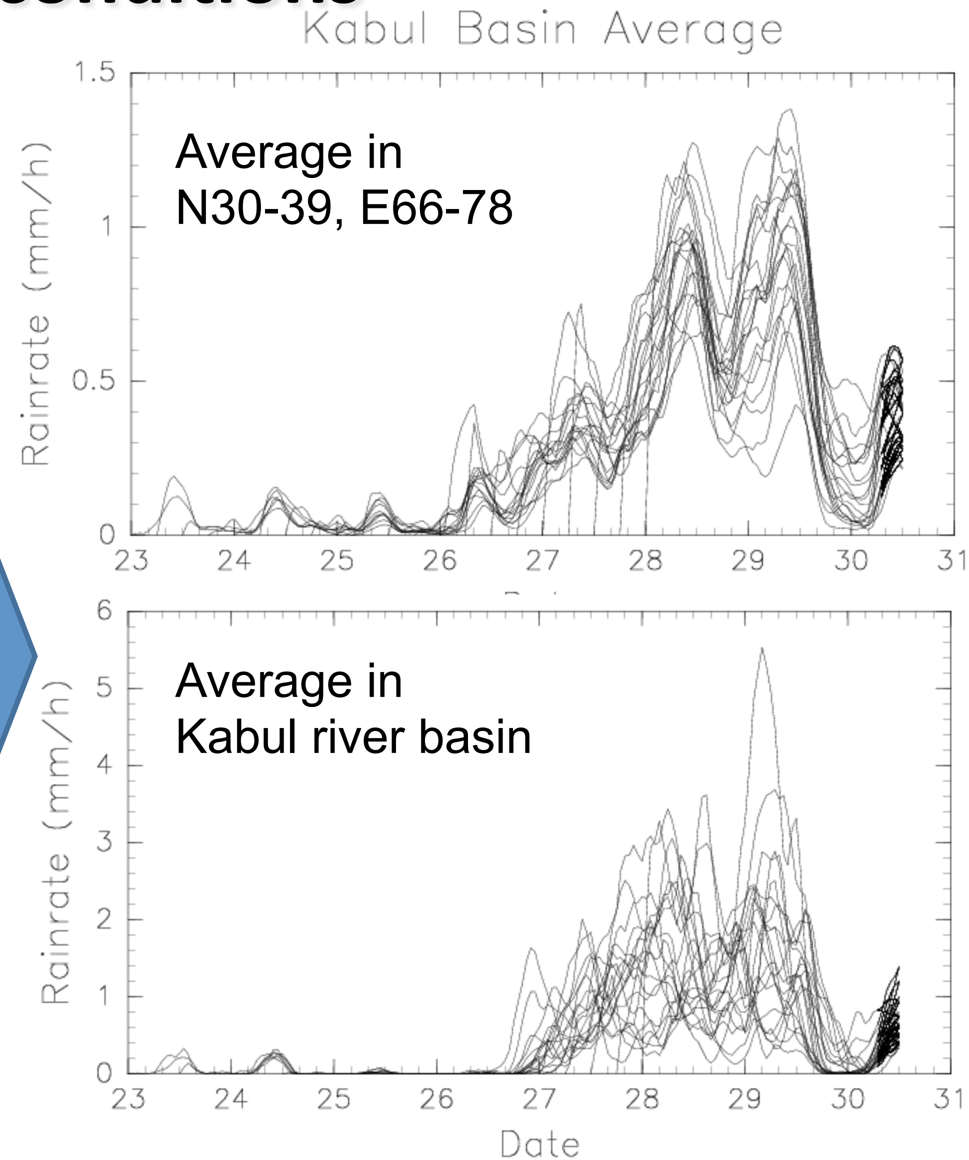
Sayama et al. (2011)

Rainfall downscaling & forecasting with different initial conditions

Ushiyama et al. (2011)







Ensemble of rainfall forecast with WRF

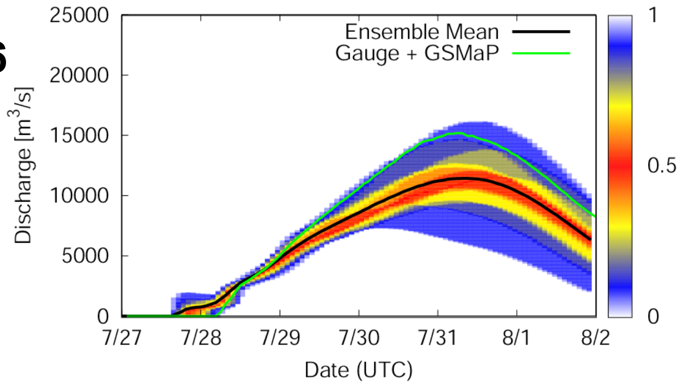
Ensemble inundation forecast with RRI Model

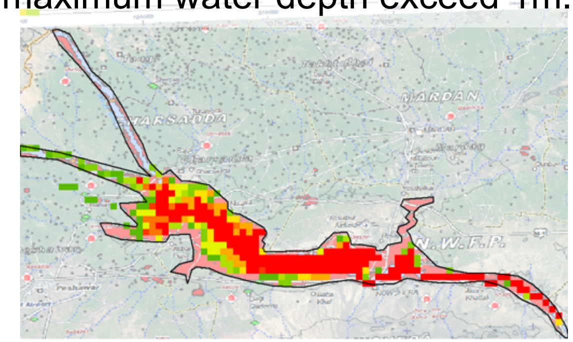
Hydrograph at Kabul
Frequency distribution by 13 members

Inundation probability
The ratio of members which maximum water depth exceed 1m.

Forecast at July 26
(23 00Z -26 00Z)

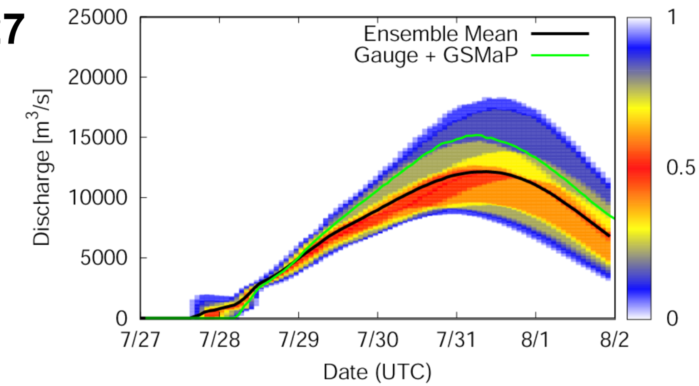
Input predicted rainfall of 13 members.

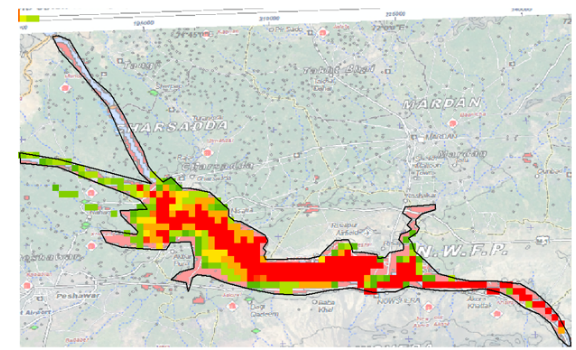


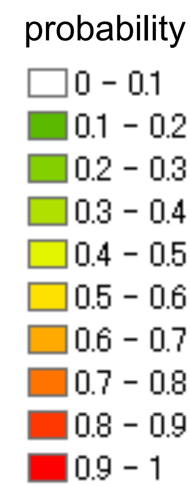


Forecast at July 27
(24 00Z -27 00Z)

✓ Ensemble members with initial condition before the beginning of rainfall gave better ensemble mean and probability range.

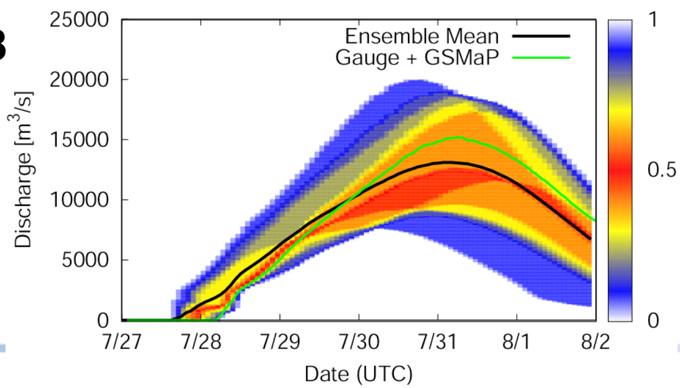


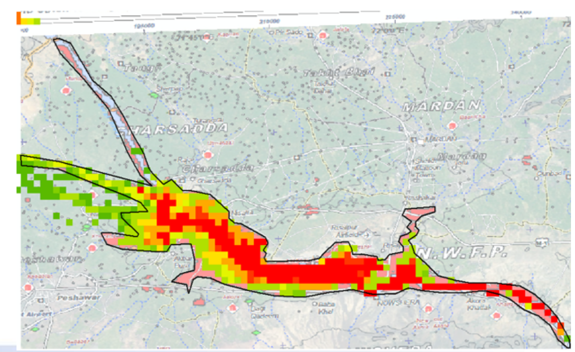




Forecast at July 28
(25 00Z -28 00Z)

✓ Ensemble members with their initial conditions during the rainfall period had large variance.





Ushiyama et al. (2011)

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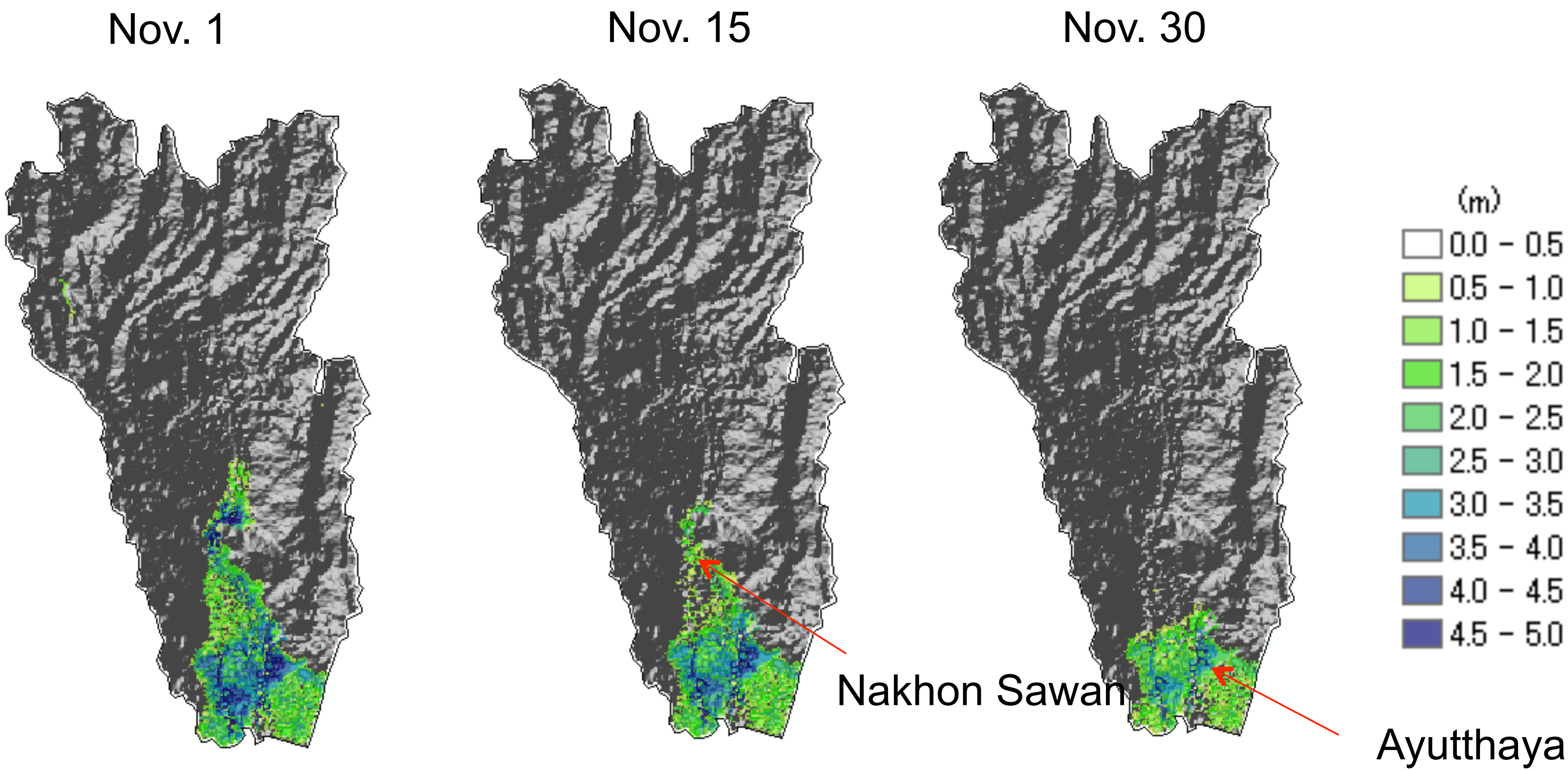
Rainfall-Runoff-Inundation model simulation for Thai Flood, 2011



- At Nov. 1, flooding still remains high around the Nakhon Sawan and Ayutthaya
- At Nov. 15, flooding around the Nakhon Sawan is reduced
- At Nov. 30, the flooding remains only partially at the northern part of Bangkok

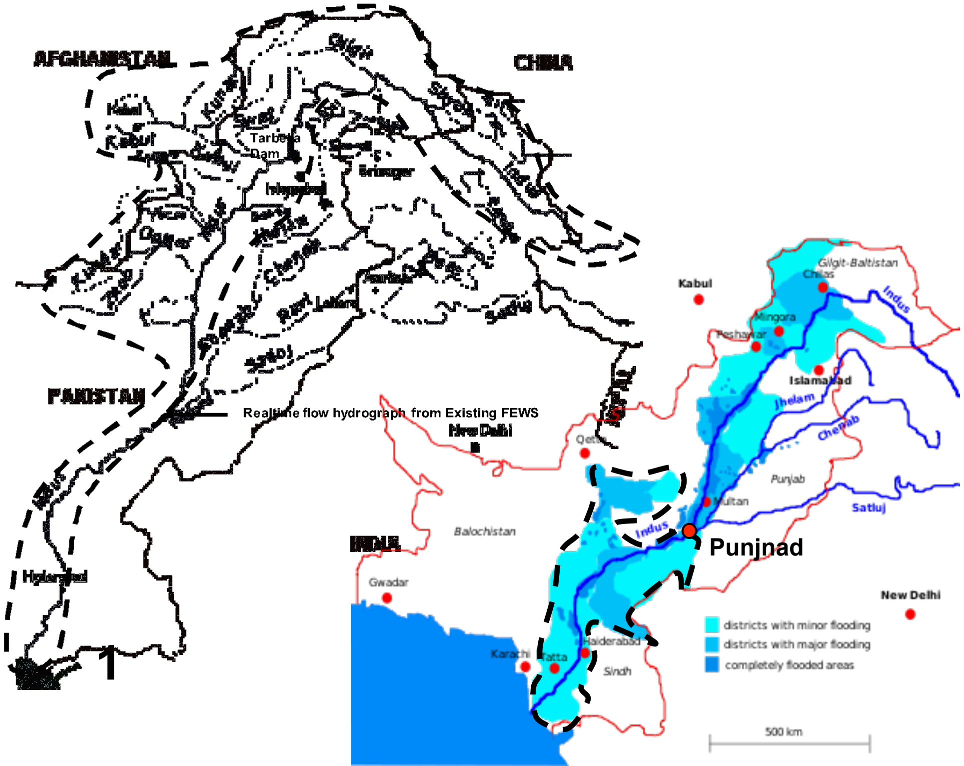
UNESCO Project (2 years: 2012-14)
Strategic Strengthening of Flood Warning and Management Capacity of Pakistan

United Nations
Educational, Scientific and
Cultural Organization

A. Strategic Augmenting of Flood Forecasting and Hazard Mapping Capacity

A-1 Development of Indus IFAS

A2- Floodplain and Hazard Mapping of Lower Indus



B. Knowledge Platforms for Sharing Transboundary Data and Community Flood Risk Information

B1. International Networking for Sharing of Transboundary Data

B2. Knowledge platform for timely national, provincial and district level data sharing

C. Capacity Development for Flood Forecasting and Hazard Mapping

- Master's Degree training at ICHARM for PMD, SUPARCO and FFC on flood forecasting/warning, hazard mapping and integrated flood management
- A short training course at ICHARM on IWRM and integrated flood management
- Training workshops in Pakistan

Example of Implementation Project for flood early warning system with satellite-based information

ADB-RETA 7276 in Indonesia to implement IFAS-based flood forecasting and warning system for the Bengawan Solo River

(FY2009-2012)

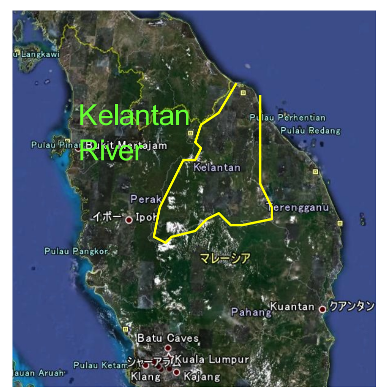
JST-JICA SATREPS Project on Research and Development for Reducing Geo-Hazard Damage in Malaysia caused by Landslide & Flood

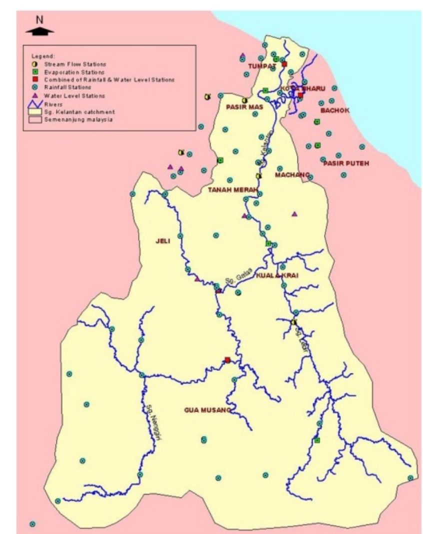
(FY2011-2015)

Flood in Dec.2007

Training Workshop with BBWS Solo in March, 2010

Major target river basin for flood: Kelantan River





Wide-range analysis: IFAS

High-res. analysis: GETFLOWS

IFAS-based flood management in ADB TA-7276-REG

- Implementing Early Warning system based on IFAS to Bengawan Solo river basin, Indonesia

  <u>* Implementing Early Warning system</u>

  <u>* Capacity Development</u>

- Community Based Disaster Risk Management project in Pacal river basin

  <u>* Creating Flood Hazard Map</u>

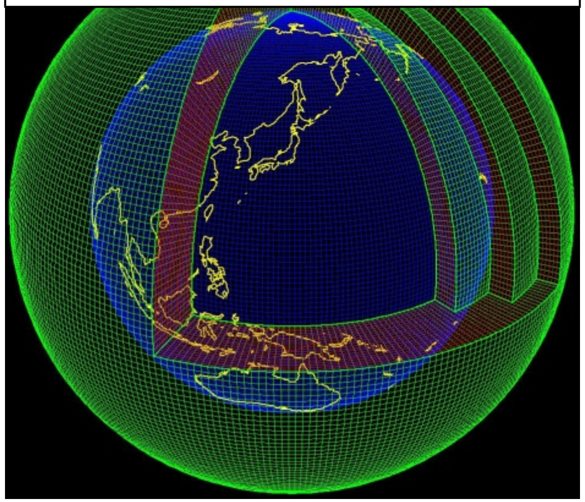
  <u>* Evacuation drill with alert by rainfall information and IFAS simulation</u>

Flood in Dec.2007

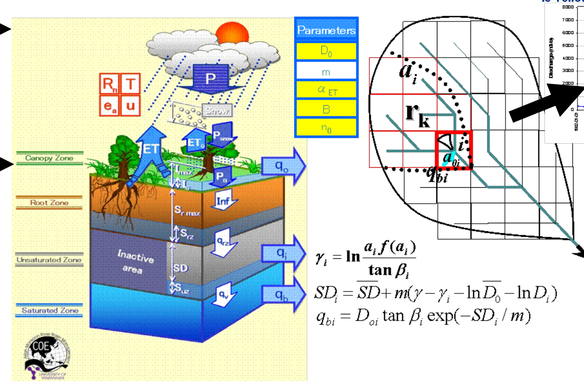
Assessment of the impact of climate change on flood disaster risk and its reduction measures over the globe and specific vulnerable areas

10-40km mesh
global stream paths

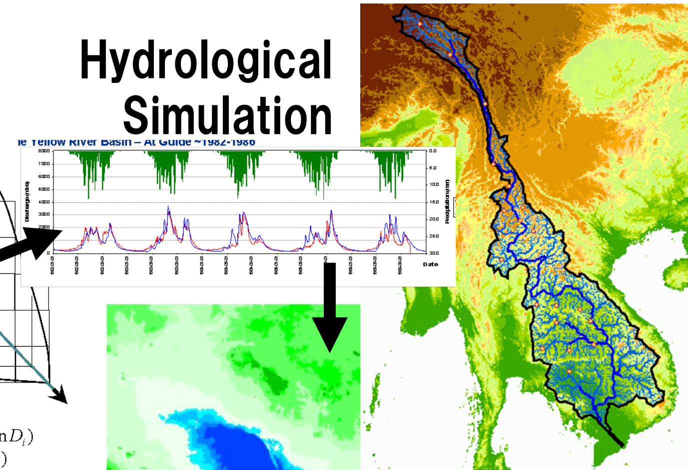
MRI-AGCM20km global
meteorological simulation

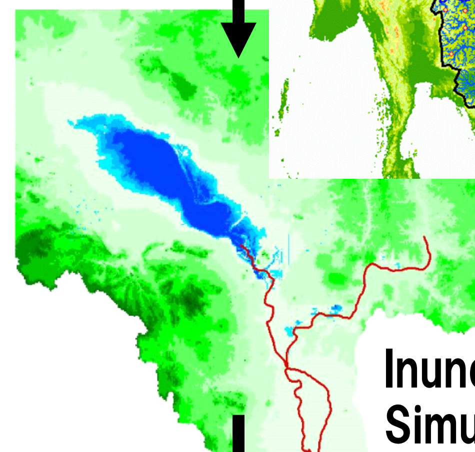


Block-wise use of TOPMODEL with
Muskingum-Cunge method (BTOPMC)

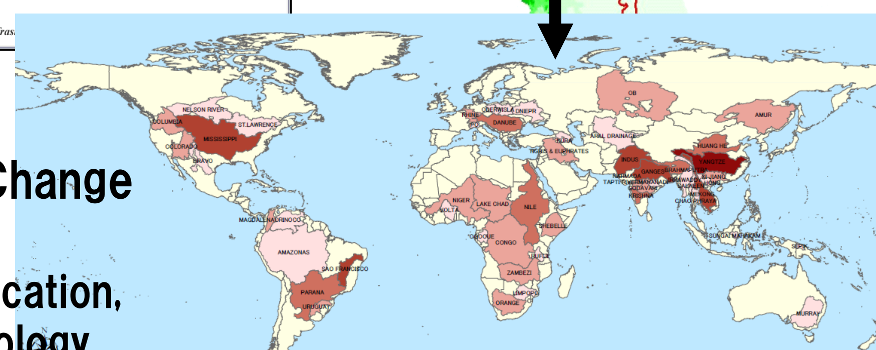


Hydrological
Simulation





Inundation
Simulation



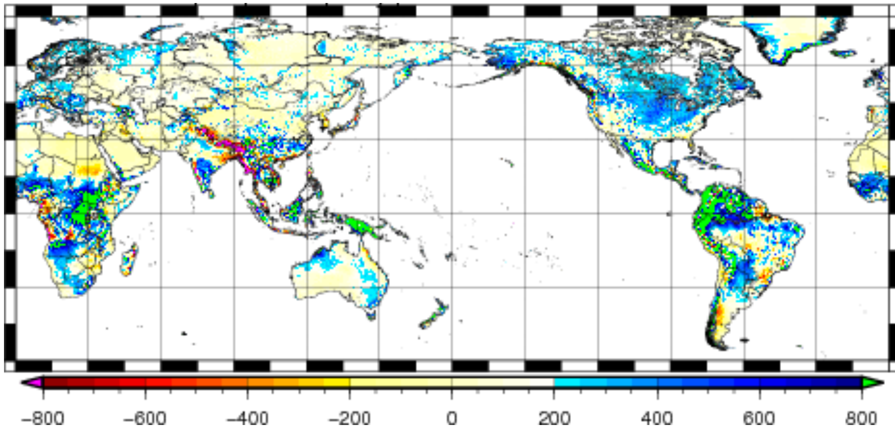
Global Flood Risk Map

KAKUSHIN

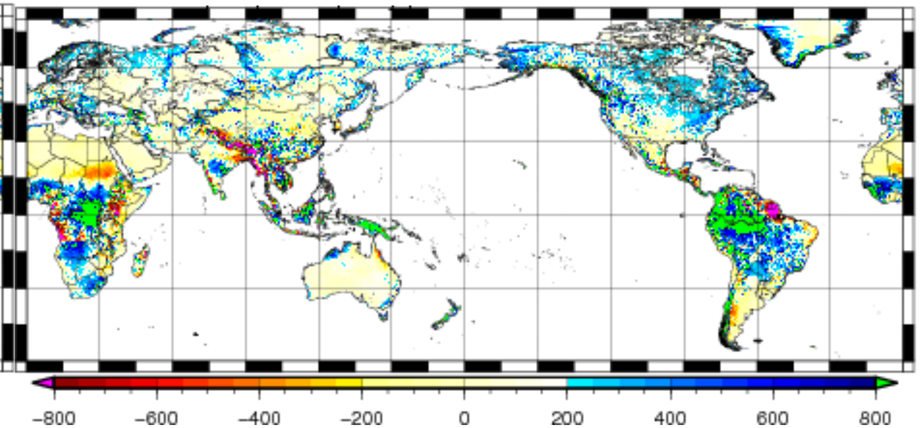
Innovative Program of Climate Change Projection for the 21st Century
funded by Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Project Period: 2007 Apr. - 2012 Mar.

Bias in MRI-AGCMs' projections of rainfall
under present climate (1980-2004)

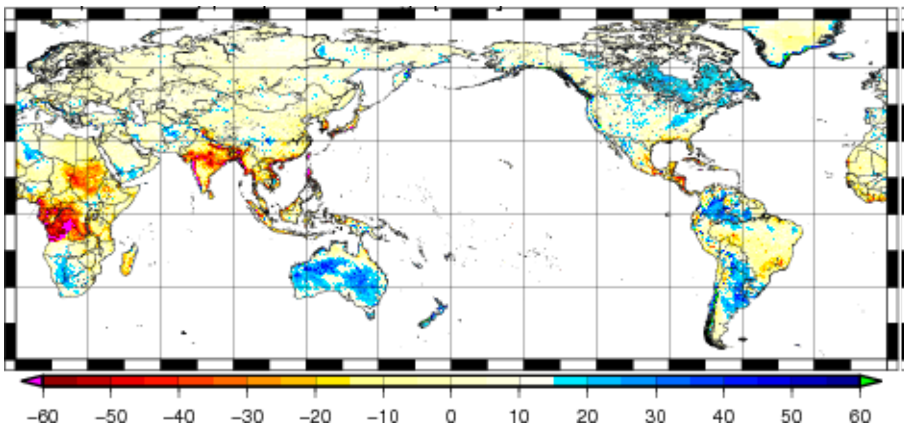


MRI-AGCM3.1S

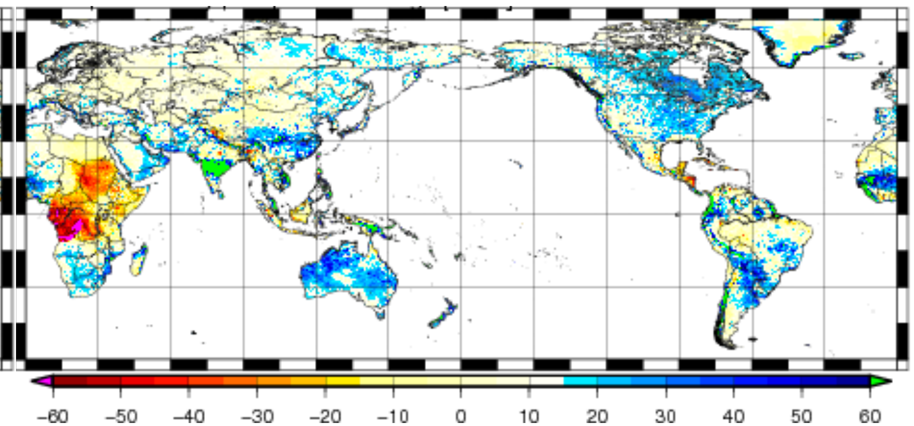


MRI-AGCM3.2S

Bias (sim.- obs.) in mean **annual** rainfall



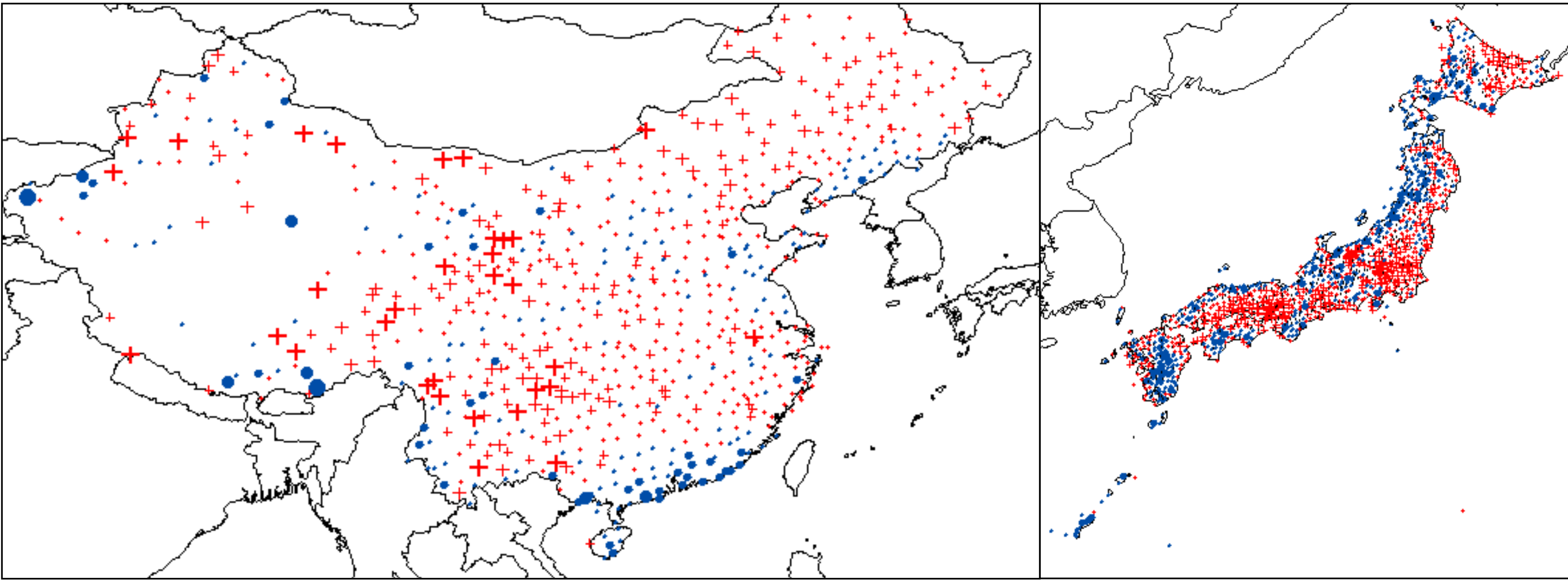
MRI-AGCM3.1S

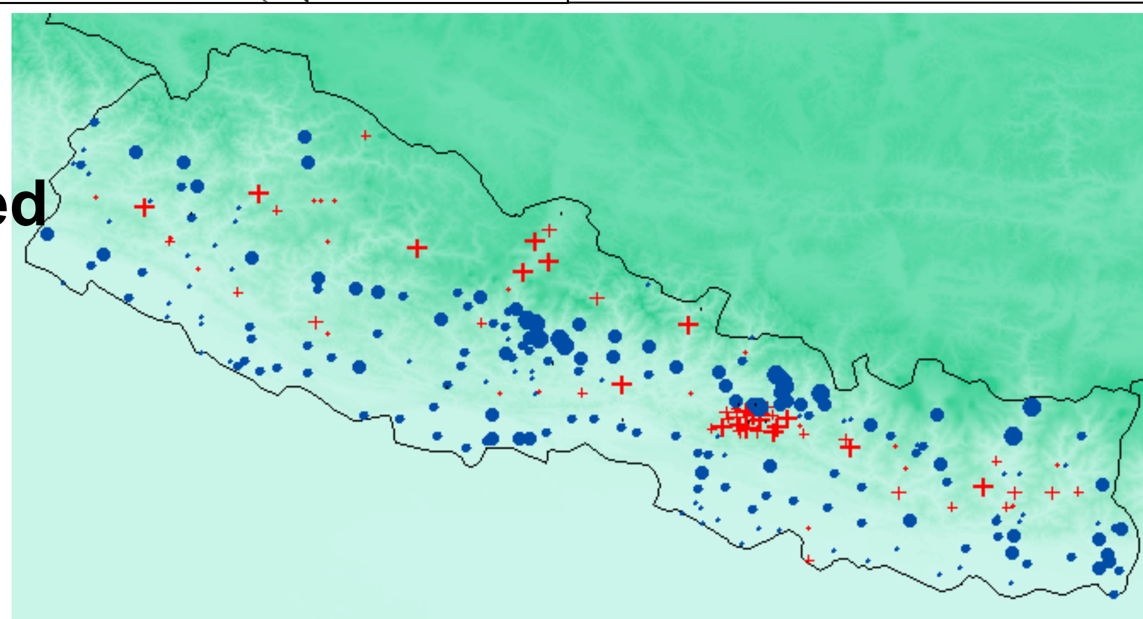


MRI-AGCM3.2S

Bias (sim.- obs.) in mean **top-0.5% daily** rainfall

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

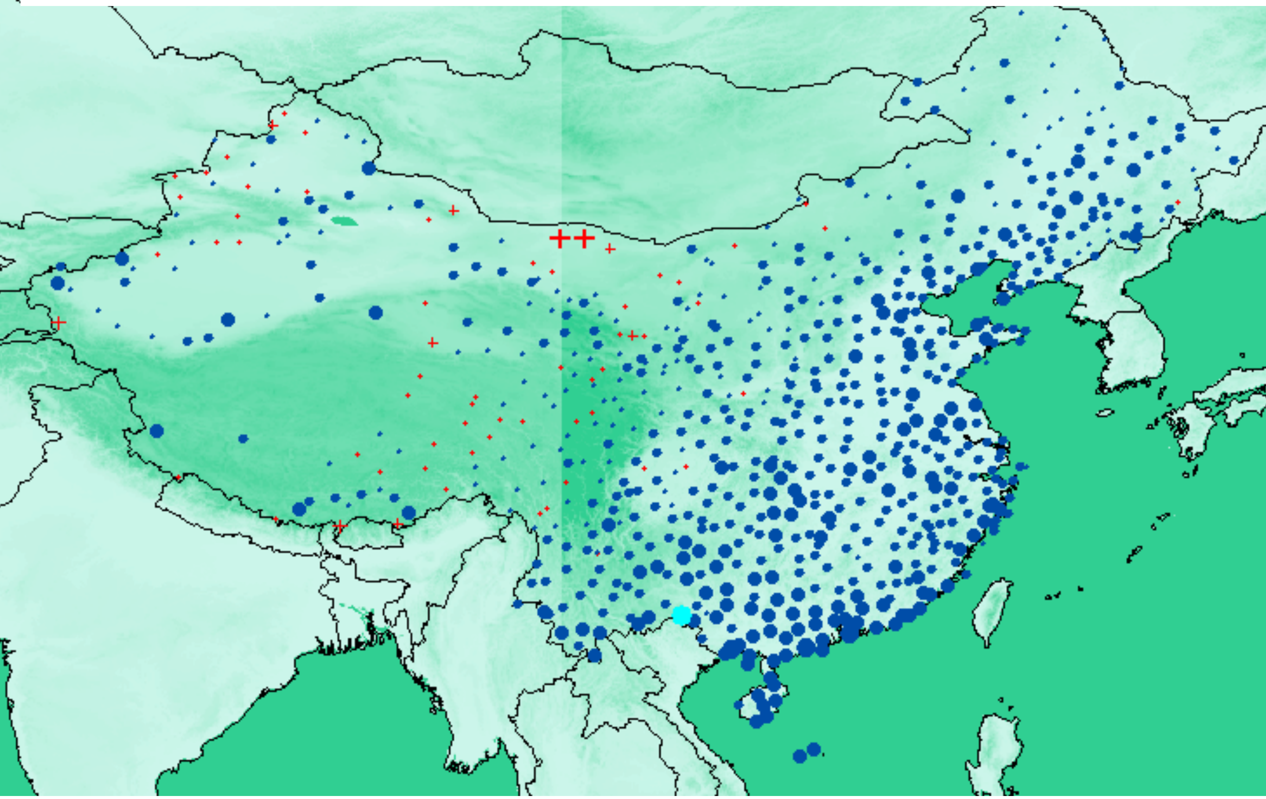


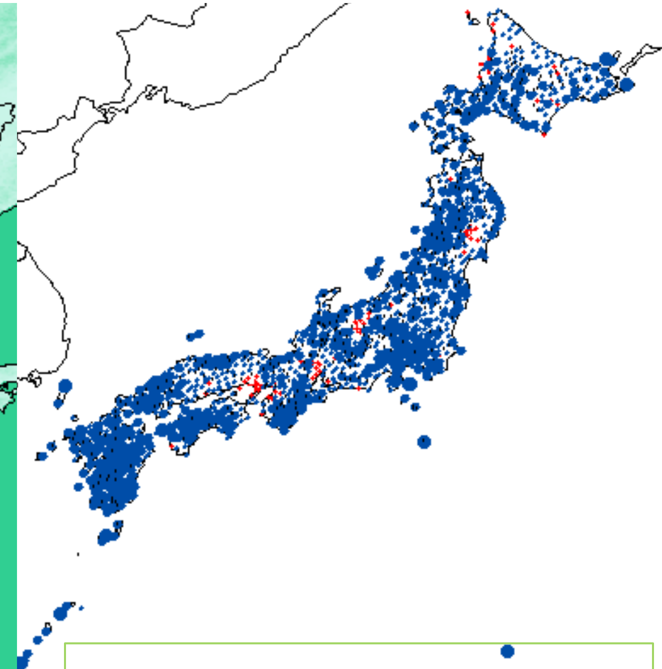


Red: Overestimated
Blue: Under-estimated

MRI-AGCM3.1S

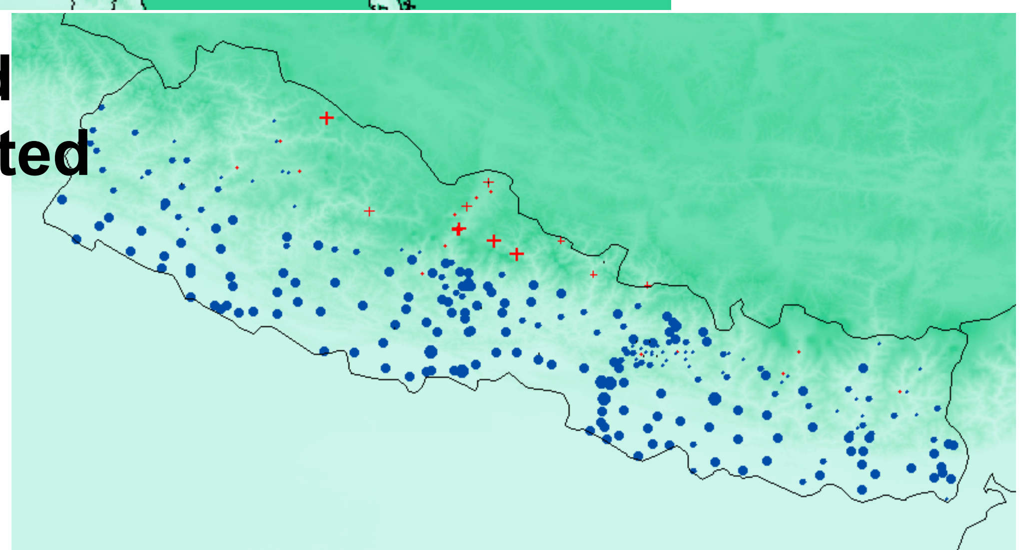
Mean annual maximum daily rainfall Sim./Obs.(1980-20



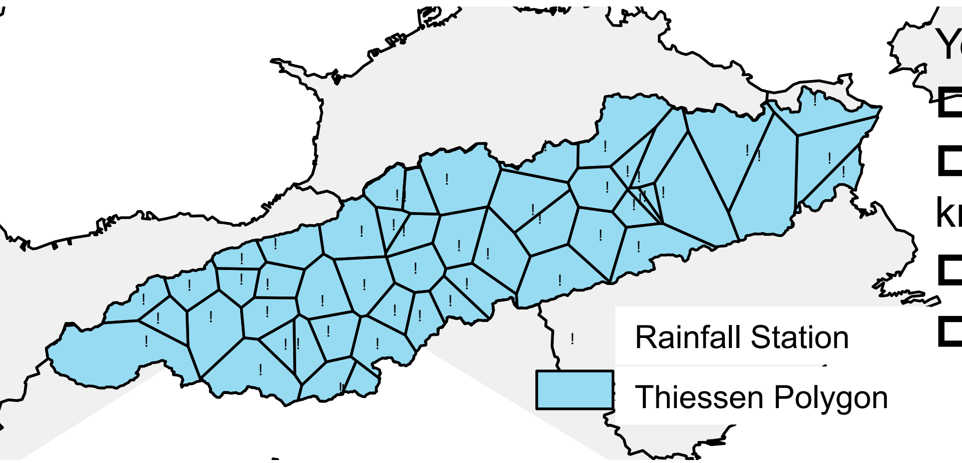


MRI-AGCM3.1S

Red: Overestimated
Blue: Under-estimated



Example of comparison（Yoshino River Basin, Japan）

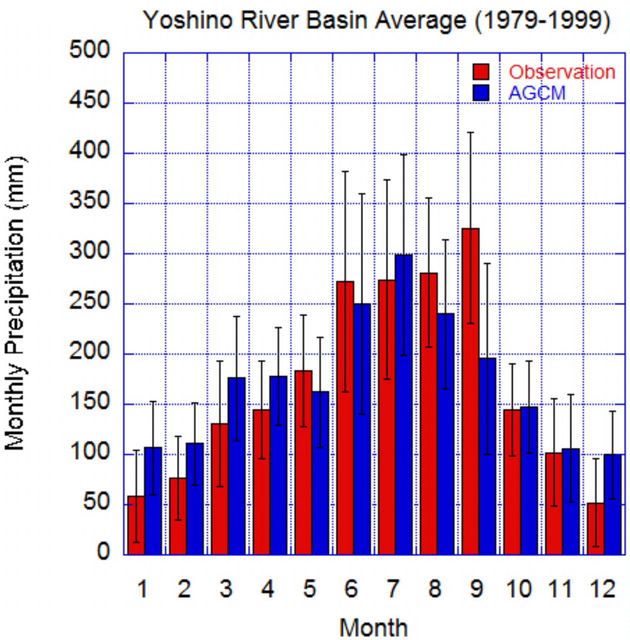


MRI-AGCM3.1S

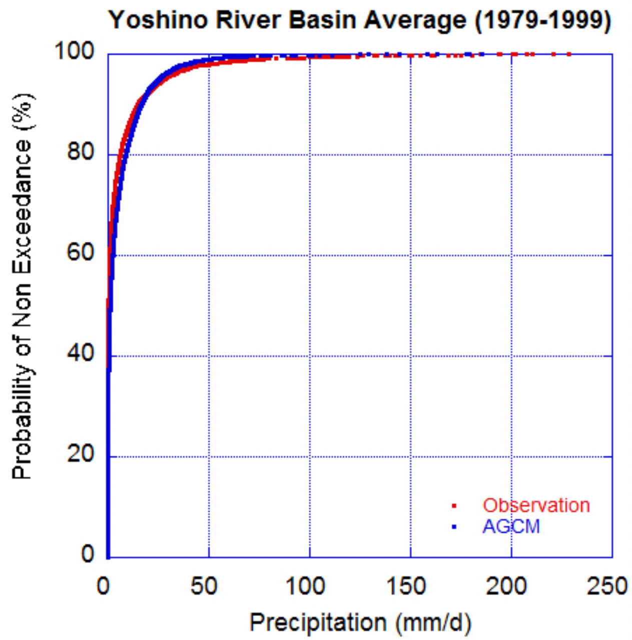
Yoshino River Basin (Japan)

- 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

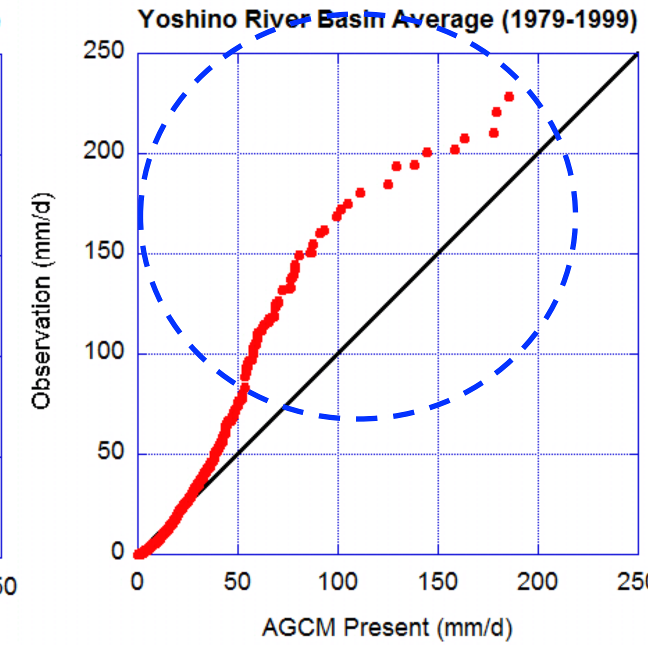
MRI-AGCM3.1S: Underestimation



Monthly Precipitation



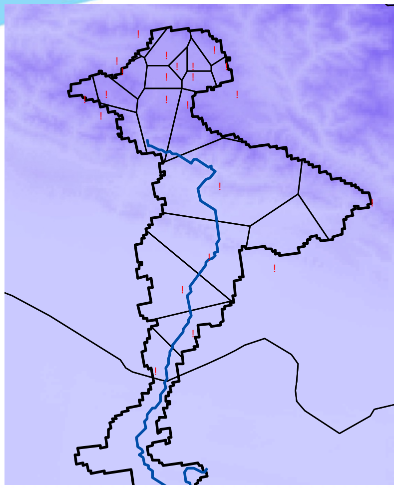
Probability of Non Exceedance (Daily Precipitation)



Quantile-Quantile Plot (Daily Precipitation)

- MRI-AGCM 3.1S 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）

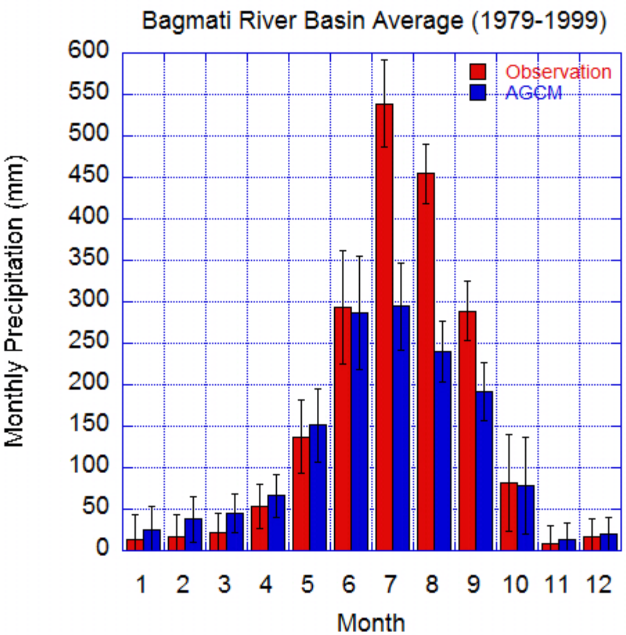


Bagmati River Basin

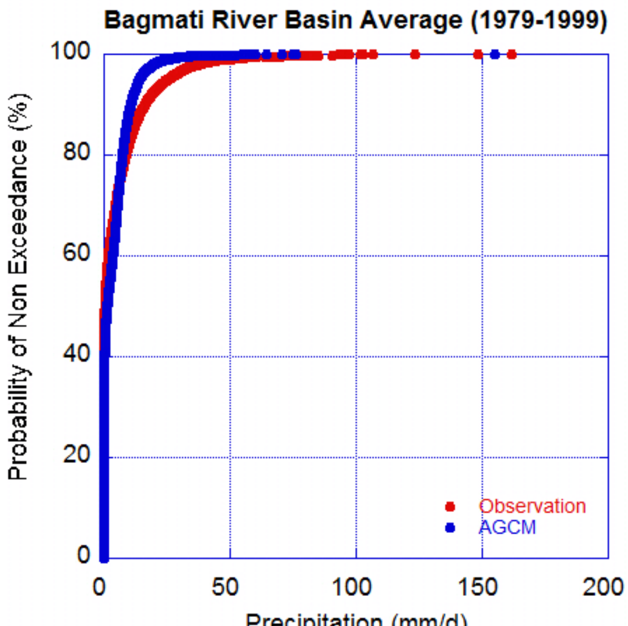
- Basin Area：4,760 km2
- It can be clearly divided into rainy (Jun. to Oct.) and dry (Nov. to May) season.
- Number of rainfall stations: 23 stations（207 km2/sta）
- Number of AGCM grid: 29
- Annual Precipitation: 1,800 mm – 2,000 mm

MRI-AGCM3.1S

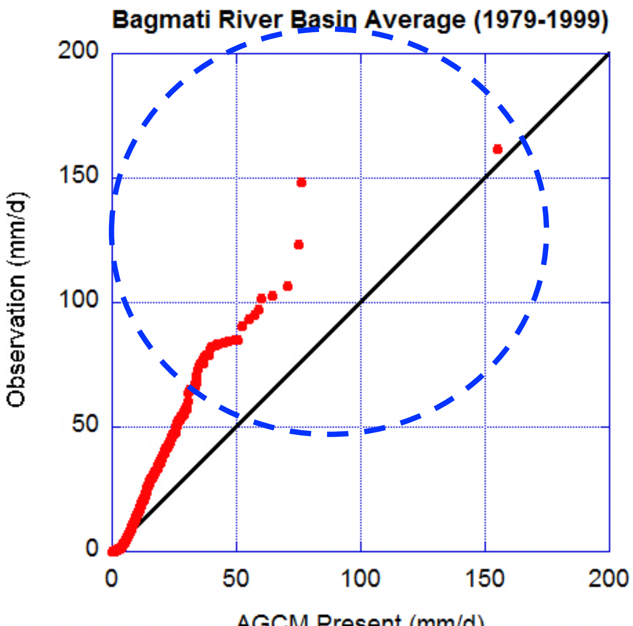
MRI-AGCM3.1S: Underestimation



Monthly Precipitation



Probability of Non Exceedance (Daily Precipitation)



Quantile-Quantile Plot (Daily Precipitation)

- MRI-AGCM 3.1S underestimates observation for heavy precipitation.
- It is necessary to apply a correction method on AGCM precipitation data for flood analysis.

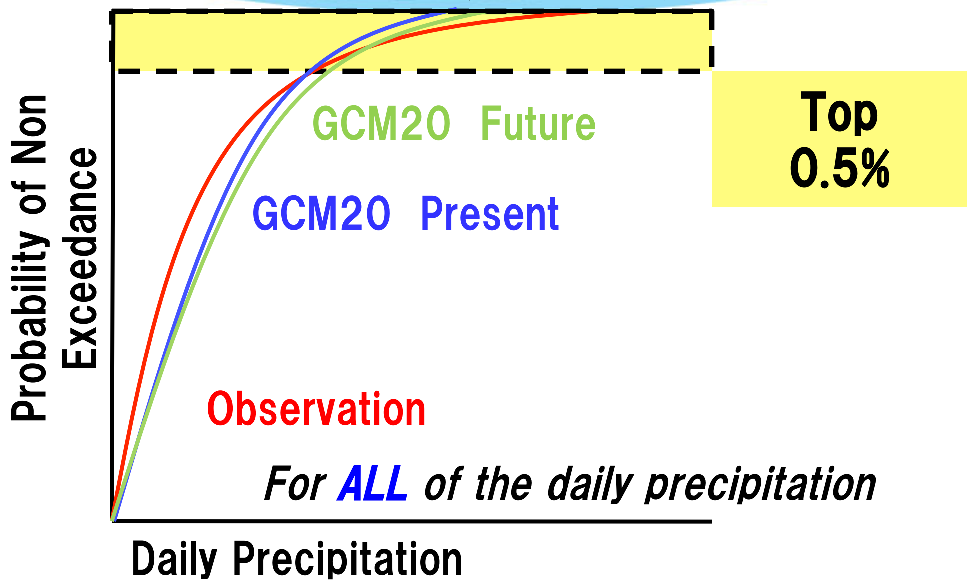
ICHARM

Concept of bias correction method for MRI-AGCM

Hybrid Quantile Method (Inomata et al., 2011)

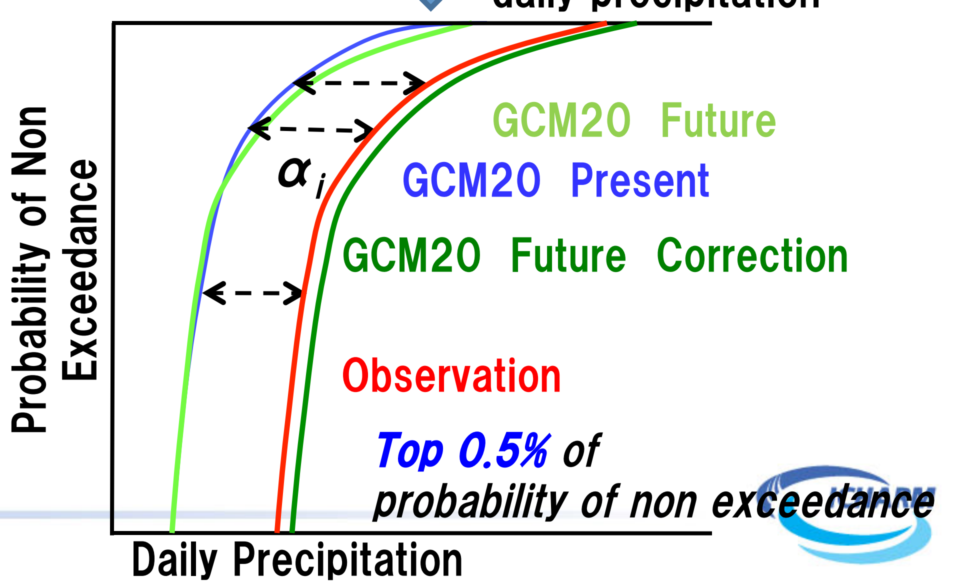
A) Extreme Value
⇒The samples in top 0.5% of prob. of non exceedance are considered.

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.

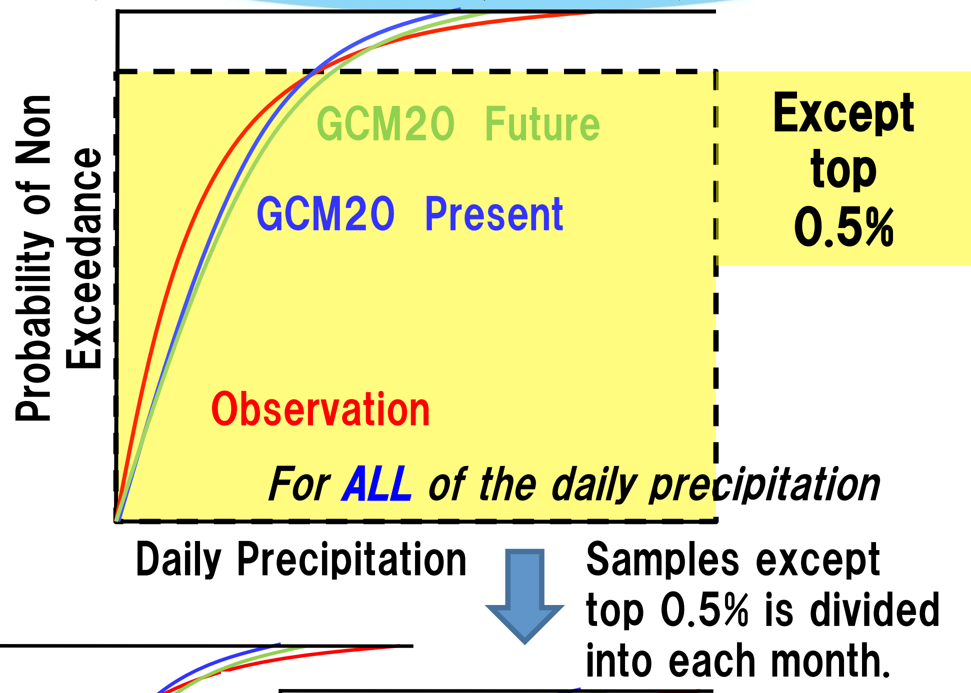
$$\alpha_i = \frac{P\_Obs_i}{GCM20\_Pre_i}$$

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

Concept of bias correction method for MRI-AGCM (continue)

Hybrid Quantile Method (Inomata et al., 2011)

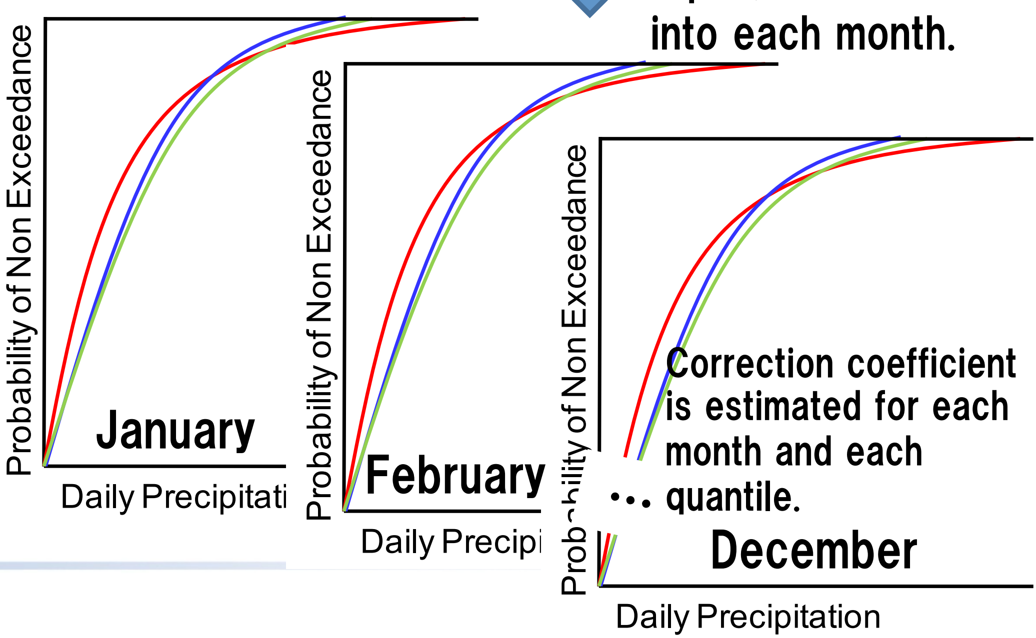
③Samples except top 0.5% on observation, GCM20 Present and Future are divided into each month.



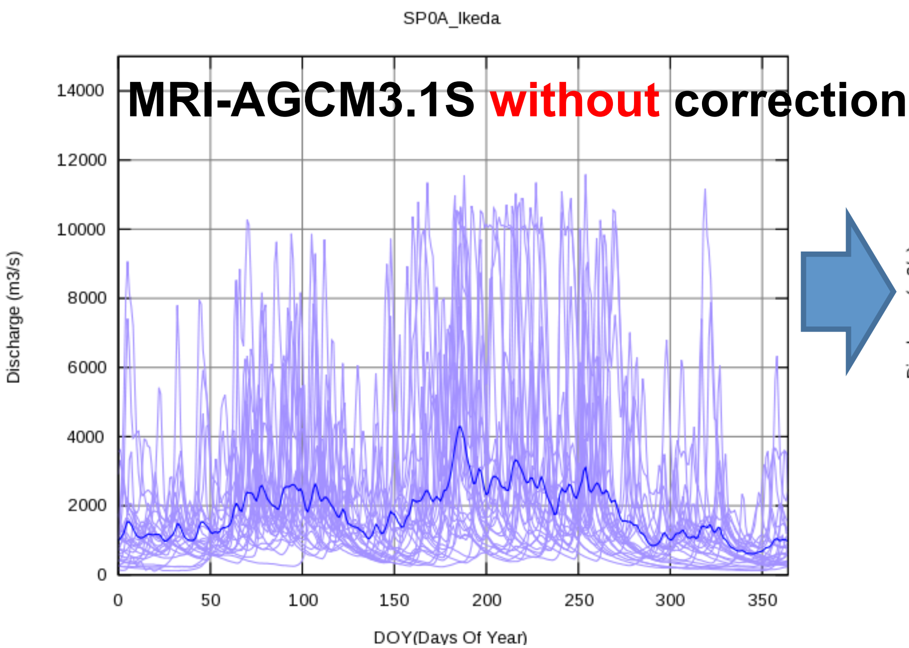
④The ratio between observation (*P_Obs$_{m_i}$*) and GCM20 Present (*GCM20_Pre$_{m_i}$*) is estimated for each month and each rank (α_{m_i}). α_{m_i} is regarded as correction coefficient and multiplied to GCM20 Future of same month and same rank (*GCM20_Fut$_{m_i}$*) and corrected value (*P_Fut$_{m_i}$*) is obtained.

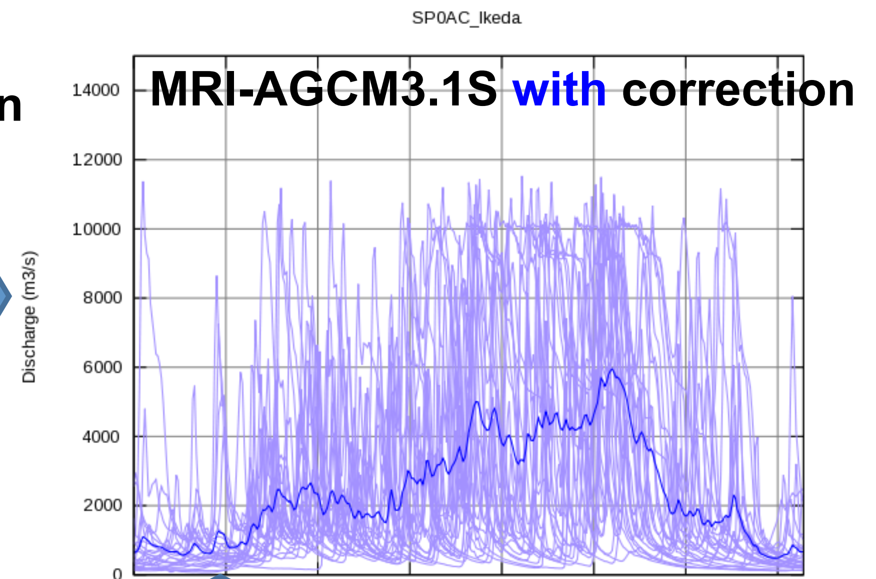
$$\alpha_{m\_i} = \frac{P\_Obs_{m\_i}}{GCM20\_Pre_{m\_i}}$$

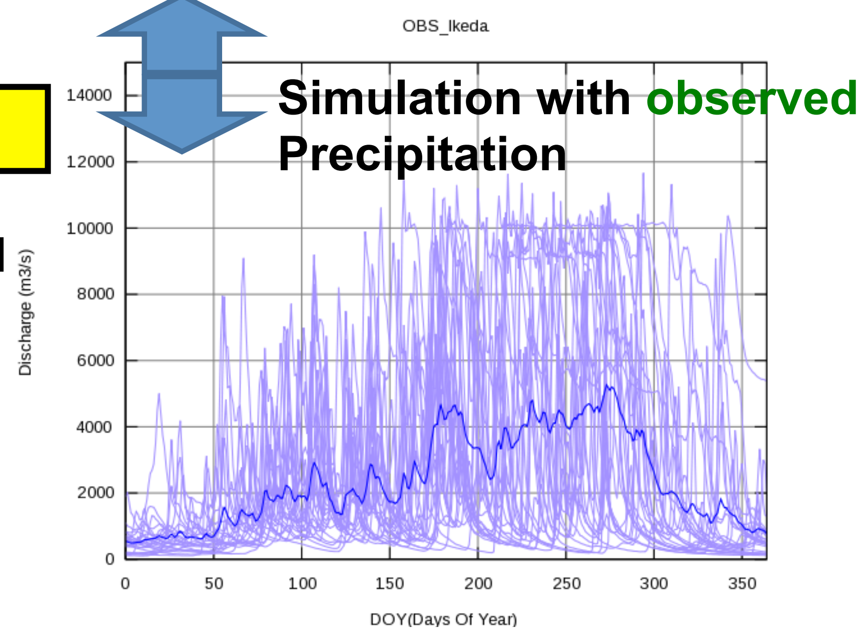
$$P\_Fut_{m\_i} = \alpha_{m\_i} \times GCM20\_Fut_{m\_i}$$



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.

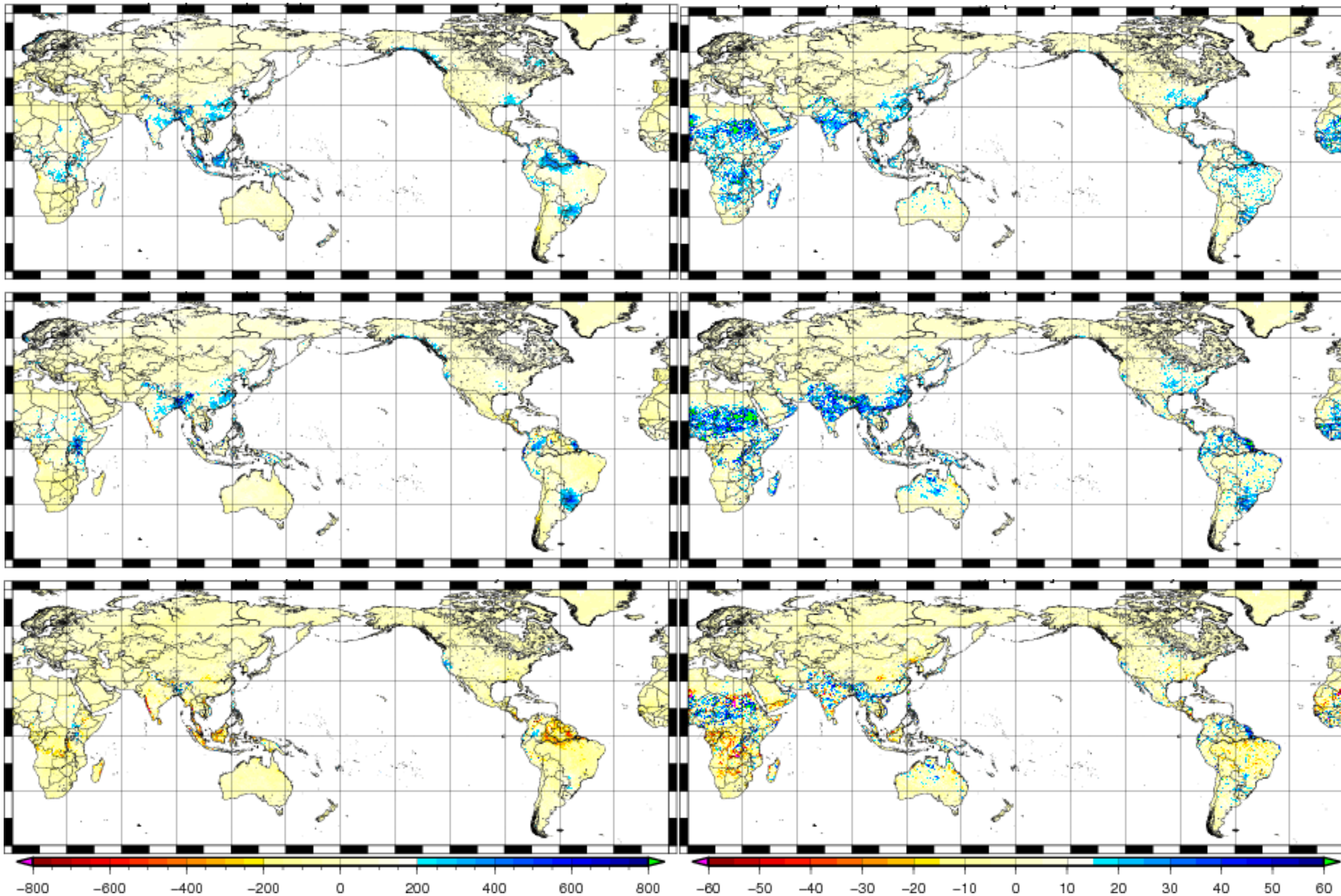
→ The runoff simulation with bias correction is just more coincident with the runoff analysis with **observed** precipitation.

Change of rainfall from Present to End-of-21c predicted by MRI-AGCMs (bias-corrected)

3.1S

3.2S

3.2S-3.1S
(Difference
of the above
two simulations)



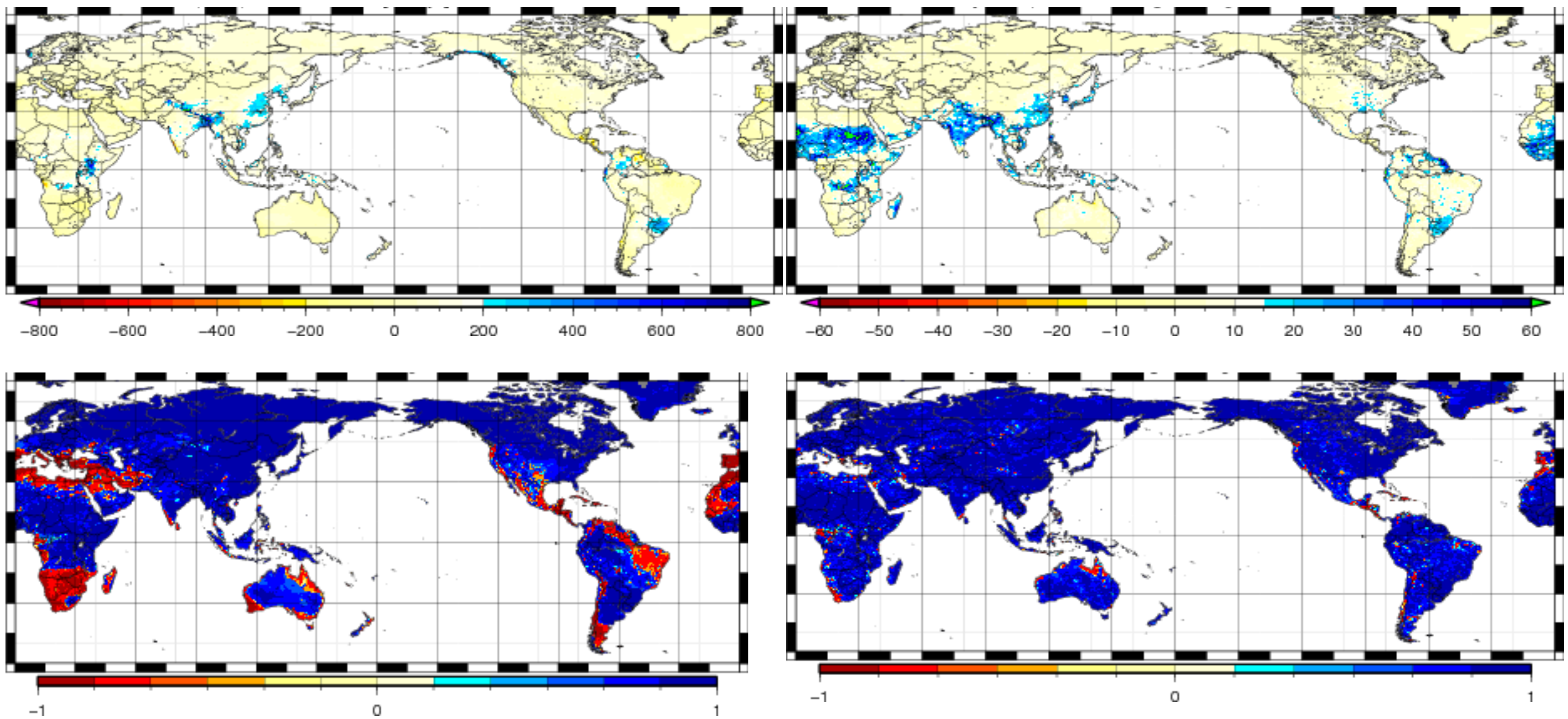
Mean **<u>annual</u>** rainfall (bias-corrected)

Mean **<u>top-0.5% daily</u>** rainfall (bias-corrected)

Ensemble average of change of rainfall
from Present (1980-2004) to End-of-21c (2075-2099) with 6 different MRI-AGCM simulations

Ensemble average of 6 models

Coincidence of change trend among 6 models (increace or decrease)



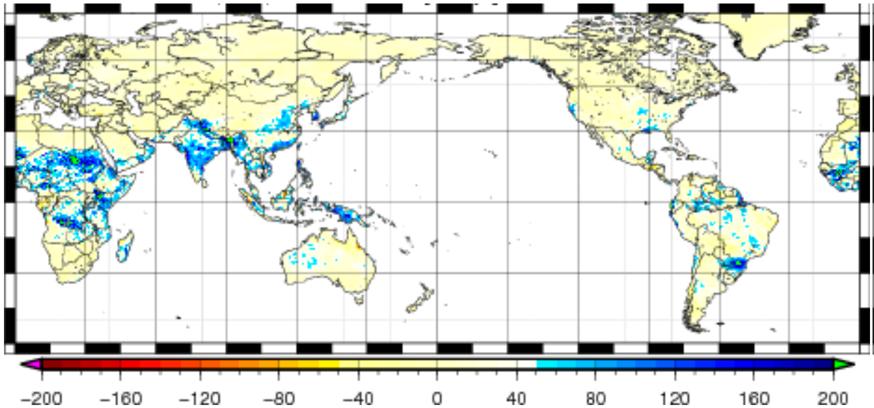
mean **annual** rainfall | mean **top-0.5%** daily rainfall

6 models = MRI-AGCM3.1S, MRI-AGCM3.2S (20km-grid), and four MRI-AGCM3.2H (60km-grid) models with different **4 scenarios on sea-surface temperature**

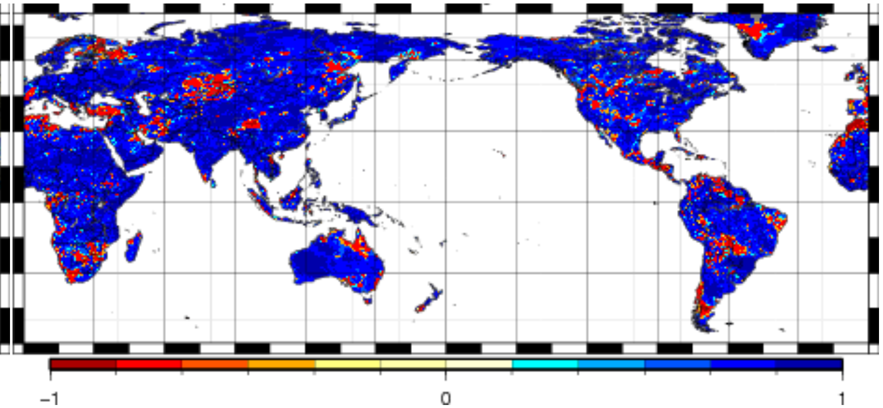
→ **Absolute quantities of rainfall changes from Present to Future may be uncertain, but the trend (direction) of the change may be more certain.**

Ensemble average of change of <u>standard deviation of annual rainfall</u> *(year-to-year variation of annual rainfall)*

from Present (1980-2004) to End-of-21c (2075-2099) with 6 different MRI-AGCM simulations



Ensemble average of 6 models



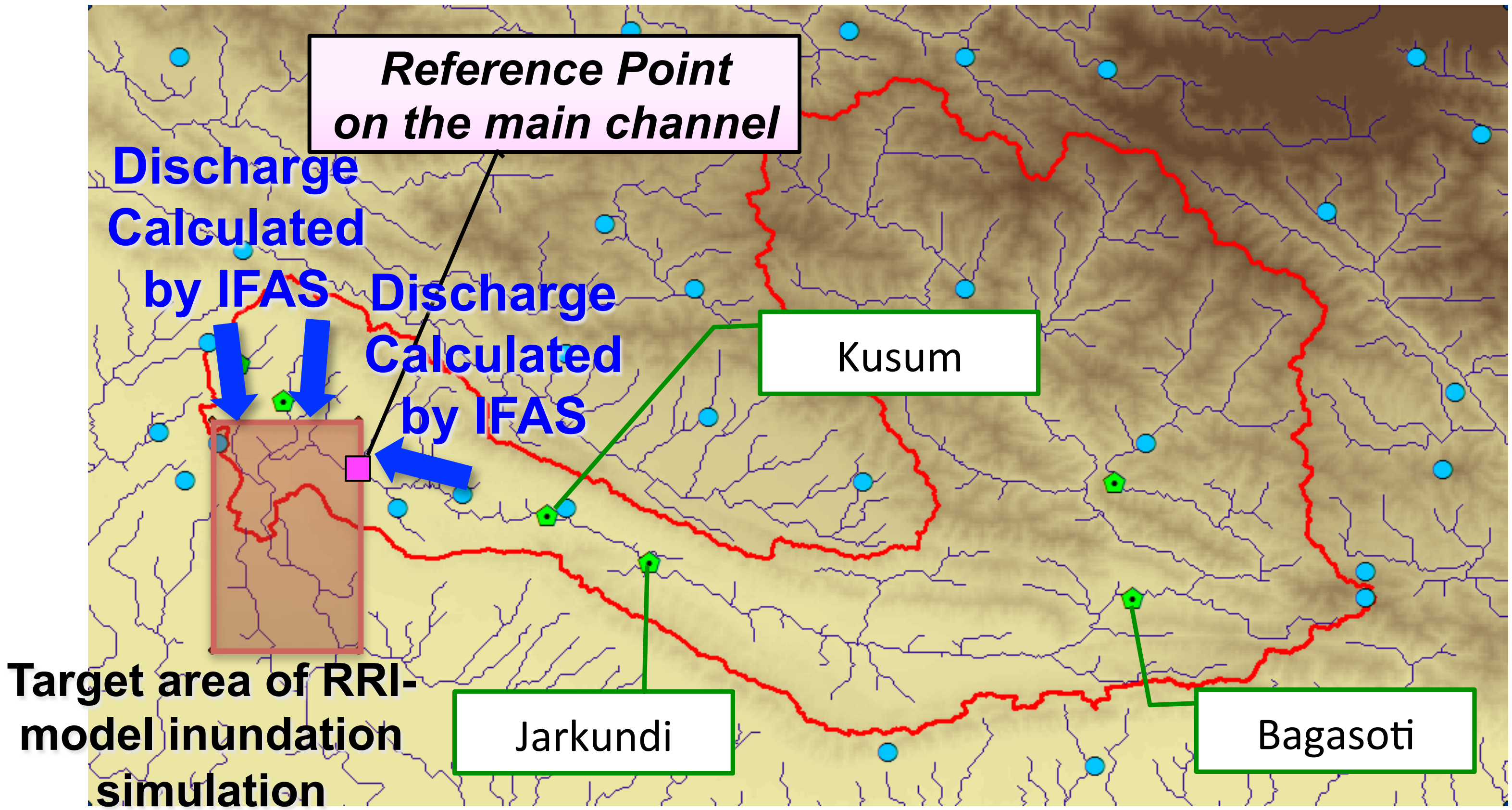
Coincidence of change trend among 6 models (increace or decrease)

→ Yearly variation of annual rainfall will increase in the future and, consequently, annual rainfall will be more unstable.

- **Objective :** To estimate the effects of climate change on extreme flood hydrographs and their peak discharges at the upstream of the alluvial-fan target area of the West Rapti River.

- Flood runoff hydrographs in the future are simulated with the PWRI distributed-parameter hydrologic model (PDHM Ver.2) on IFAS.
- Flood inundation extent, depth and duration is evaluated with the ICHARM RRI model.

IFAS : Integrated Flood Analysis System
RRI Model : Rainfall-Runoff Inundation Mod



Flow of Runoff Prediction using IFAS

Observed rainfall and discharge

Setting and tuning PWRI distributed-parameter precipitation-runoff model

Precipitation-runoff simulation using projected precipitation

25-year daily series of river flow simulation for each period (present, near future & end-of-21st century)

Frequency analysis of flood peaks above a threshold level

Probable extreme flood peak discharge coressponding to the return periods: 25 and 50 years

Projected precipitation from MRI-AGCM 3.1S and 3.2S

Bias corrected daily precipitation

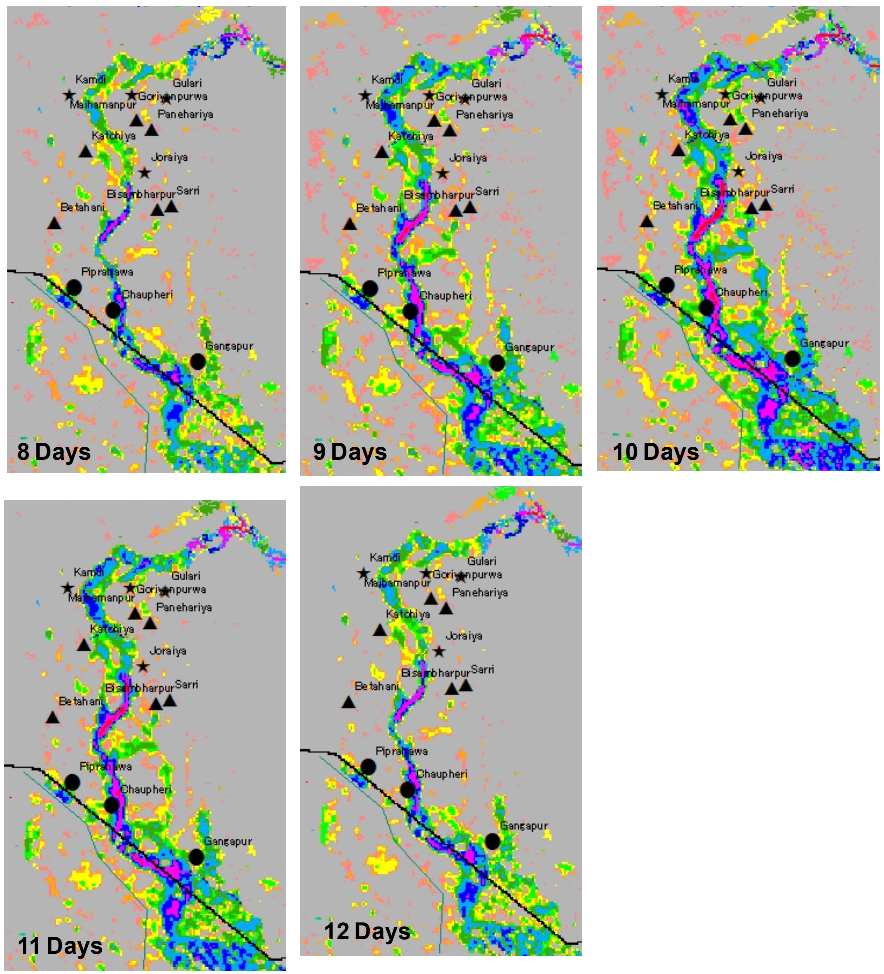
Present : 1980~2004

Near Future : 2015~2039

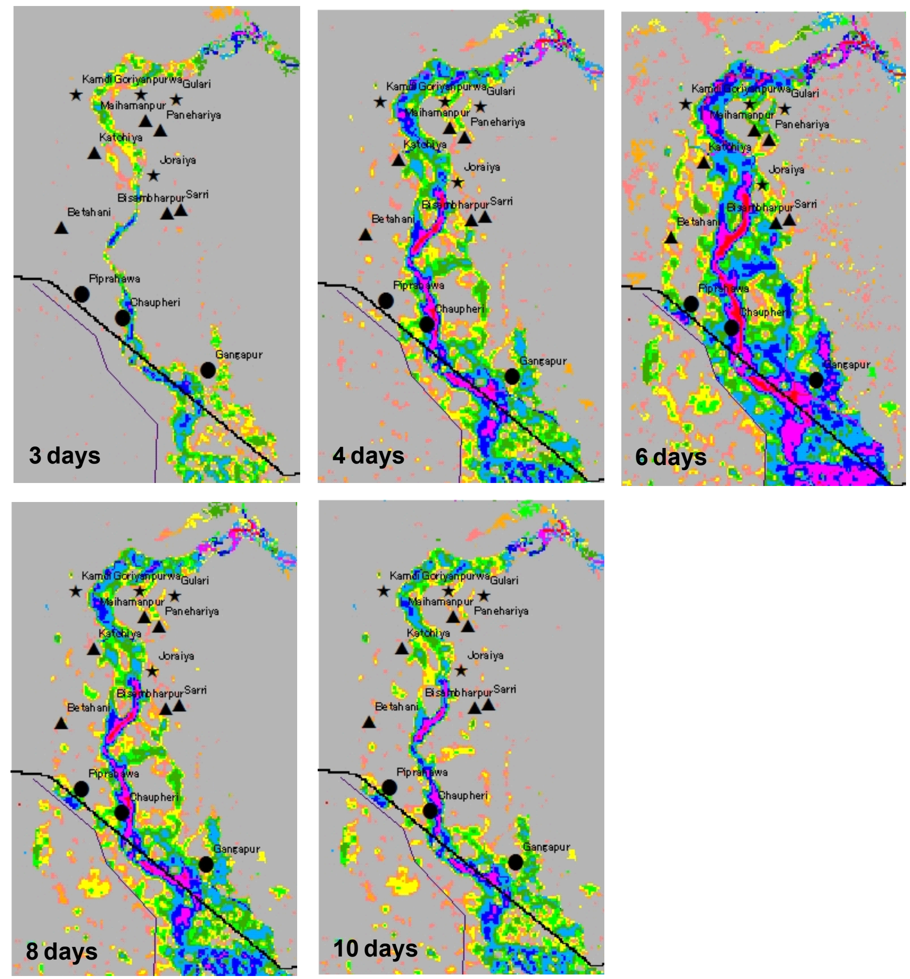
Future : 2075~2099

Inundation simulation with RRI model

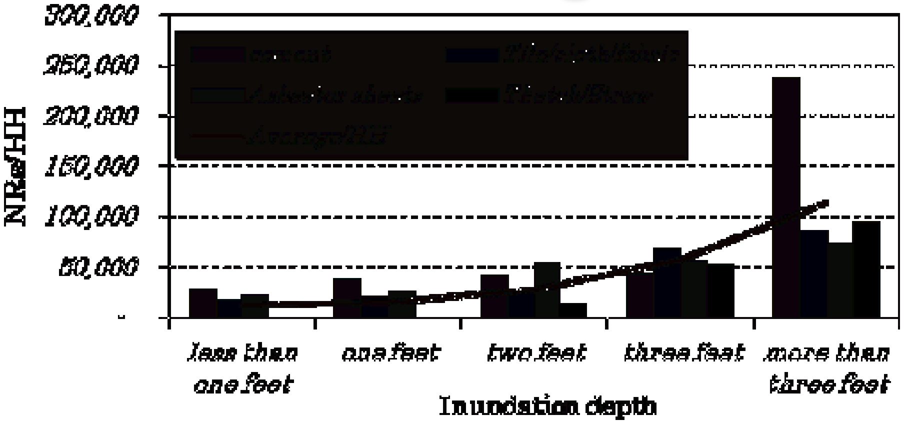
Inundation Simulation Results for MRI-AGCM 3.2S SPAC-3 (present climate) Probable Discharge = 4658 m^3/s (1/50)



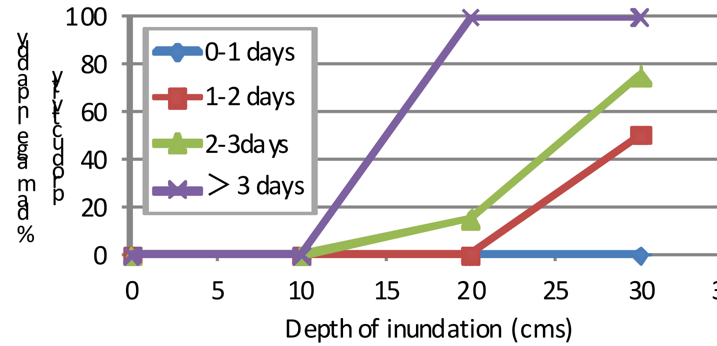
Inundation Simulation Results for MRI-AGCM 3.2S SFAC-3 (end-of-21st century climate) Probable Discharge = 8806 m^3/s (1/50)



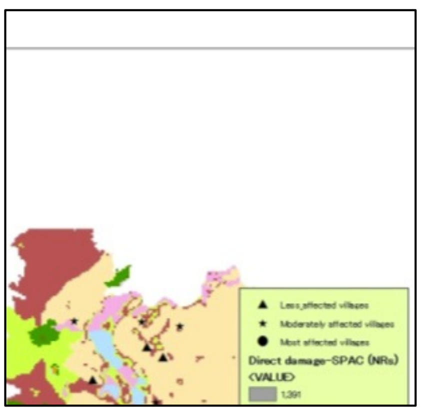
Evaluation of damage curves & flood risk change for West Rapti, Nepal



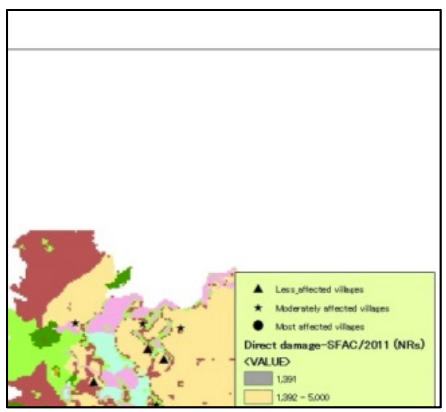
Damage curve for household



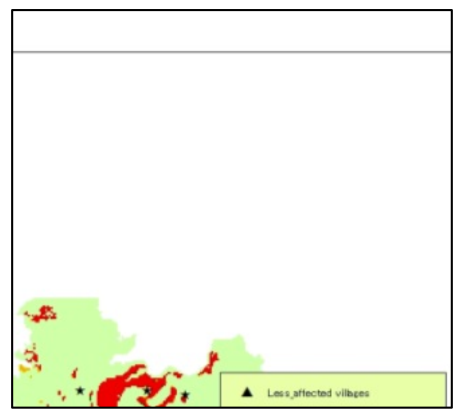
Damage curve for agriculture (rice, growing period)



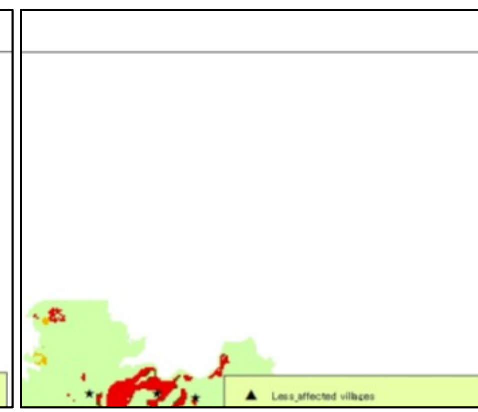
Present



End of 21st Century



Present



End of 21st Century

Change of flood damage on households (left) & rice (right) based on present monetary value

Source: ICHARM & NDRI

Capacity Development Programs

- **Short training courses**
  - Flood hazard mapping (FHM) course (2004-2008, JICA)
  - Local emergency operation plan with FHM (2009-, JICA)
  - River and Dam engineering course (1973-, JICA)
  - Comprehensive Tsunami training (2008, UNISDR)
- **Aftercare program** for implementation at trainees local communities (2006-, JICA)
  - KL, 2007; Guangzhou, 2008; Manila, 2009; Hanoi, 2010
- **Master Course on Water-related Disaster Management** with National Graduate Institute for Policy Studies (GRIPS) supported by JICA since October 2007
  - 10 students from Bangl., China, India, Nepal, Japan (2008)
  - 8 students from Bangladesh, China, Indns, Nepal, Ethiopia, Thai. (2009)
  - 12 students (2010), 15(+4) students (2011)
- **PhD Course** with GRIPS 1 student (2010), 3 students (2011)

Thank you for your attention!

k-fukami@pwri.go.jp

ICHARM / PWRI