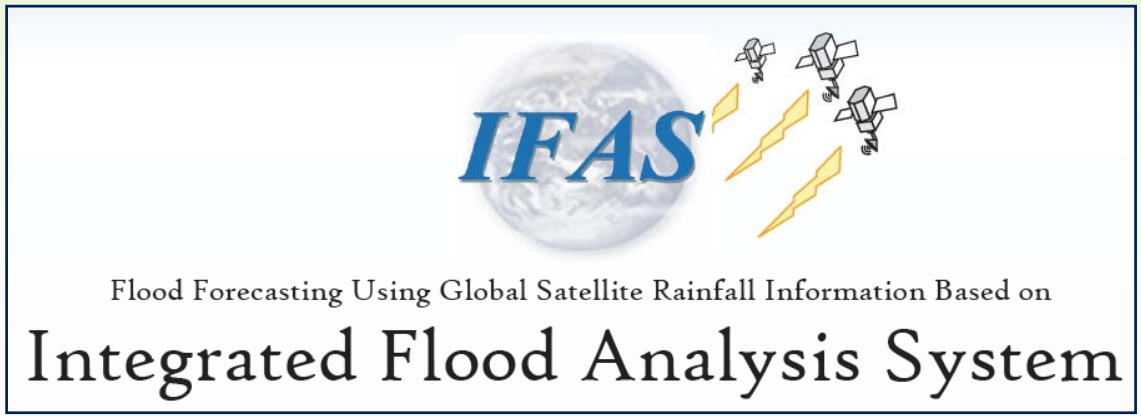
Technology for Flood Forecasting System



1) Objective and concept of GFAS-Streamflow and IFAS

by Kazu FUKAMI

2) Major features and functions of IFAS for poorly-gauged river basins

by Jun MAGOME

Hydrologic Engineering Research Team,
International Centre for Water Hazard and Risk Management (ICHARM)
Public Works Research Institute (PWRI)

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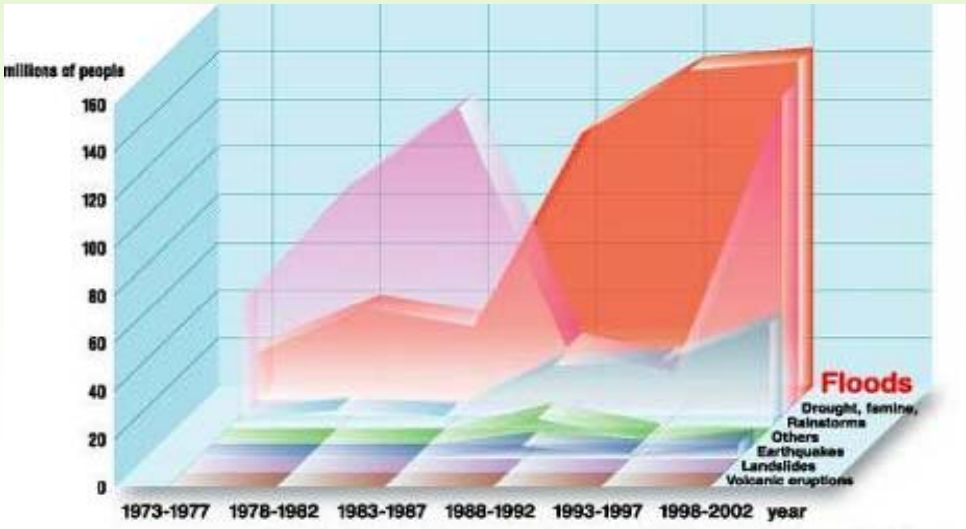
Flood disaster is still increasing…

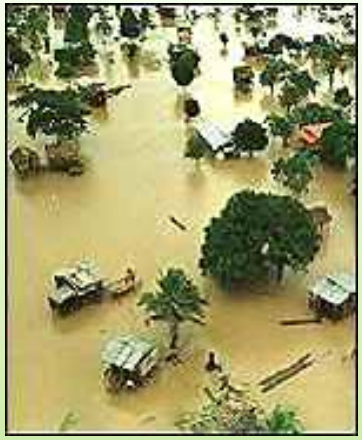


Average numbers of people affected by natural disasters (1973-2002)

Source: “World Disaster Report 2004”

International Federation of Red Cross and Red Crescent Societies

- Aug. 2007: Nepal-India-Bagladesh
- Nov. 2007: Cyclone Sidr (Bangladesh)
- May 2008: Cyclone Nargis (Myammar)
- July-Sep. 2008: Many guerrilla storms (Japan)
- Aug. 2008: Mississippi River (USA)
- Aug. 2008: Hurricane Gustav (Caribbean countries)
- Sep. 2008: Hurricane Ike (Caribbean countries)
- Etc…..



Priority actions

January, 2005

UN World Conference on Disaster Reduction (Kobe)

Hyogo Framework for Action 2005-2015:

-Building Resilience of Nations and Communities to Disasters-

1) Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation.
2) Identify, assess and monitor disaster risks and enhance early warning.
3) Use knowledge, innovation and education to build a culture of safety and resilience at all levels.
4) Reduce the underlying risk factors.
5) Strengthen disaster preparedness for effective response at all levels.

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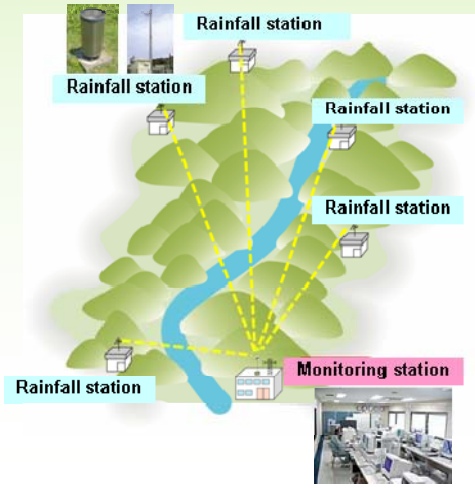
Flood disaster mitigation
with flood forecasting and warning systems



1. **Monitoring of meteorological & hydrological conditions**

2. **Flood – runoff modeling**
   - Building rainfall forecasts & runoff analysis

3. **Analysis of forecasts and judgments on the degree of hazards and risk**

4. **Dissemination of warnings**

5. **Crisis management**
   - migration of residents and livestock,
   - re-planning of agricultural schedule (seedings, fertilizing, harvesting, etc.)
   - flood fighting, evacuation, etc.

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Flood disaster mitigation with flood forecasting and warning systems

(Typical situations in developing countries)

1. Monitoring of meteorological & hydrological conditions

- × Low density of gauging stations, low sustainability of maintenance of observatories, etc.

2. Flood – runoff modeling

- × Lack of hydrological and geophysical data for modeling
- × Lack of budget and capacity to construct and run the forecasting & warning system

3. Analysis of forecasts and judging risks

- × Lack of real-time hydrologic data
- × No information to identify reliability and uncertainty
- × Lack of capacity to maintain and improve the system with new accumulated data and changing situations

4. Dissemination of warning

- × Lack of disaster-management community and communication network,
- × Incompatibility of flood information with local society and needs, etc.

5. Crisis management

- × Improper governance and preparedness
- × Insufficient institutional cooperation, etc.

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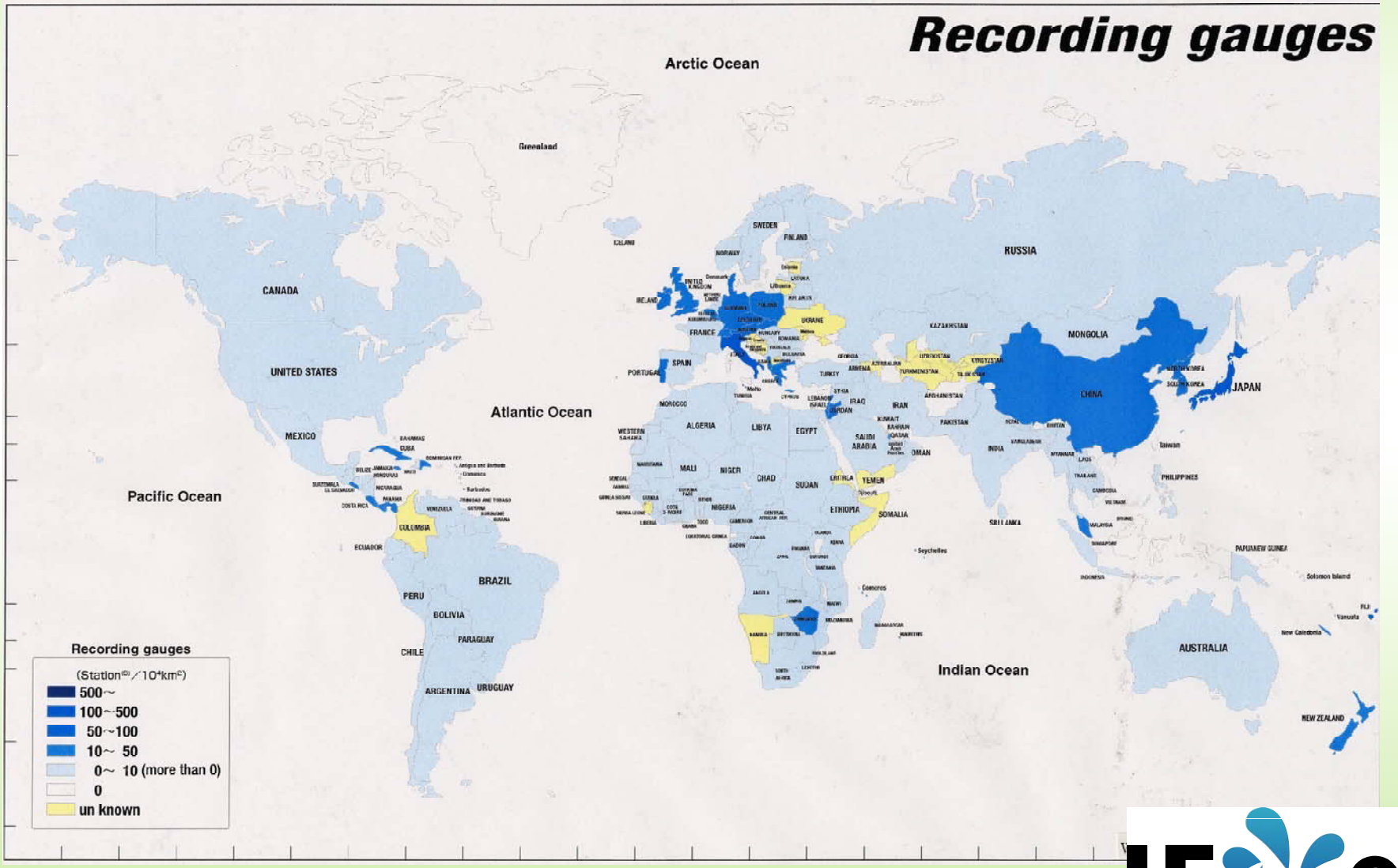
Recordable Gauges



Data source: WMO

IFNet
International Flood Network

Technical issues

for flood forecasting in poorly gauged or ungauged basins

- How can we prepare necessary (historical and real-time) hydrologic and geophysical data for rainfall-runoff modeling as the basis for flood forecasting and warning systems **in poorly-gauged river basins**, especially **in developing countries**?

- What kind of hydrologic (rainfall-runoff) model is suitable for ***"worldwide applicable"*** flood forecasting system under the condition of **very limited (hydrologic & geophysical) in-situ data availability**?

- Big necessity to prepare any **easy and efficient tool** just fit to the objective above, with **user-friendly** interfaces and **minimal cost** to implement?

- How should the system be to **sustain the effectiveness and reliability** of the implemented system under changing situations?

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Technical issues

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Enhancement of Global Flood Alert System (GFAS) concept of IFNet

- GFAS – Rainfall
- GFAS – Streamflow

ICHARM

Technical issues

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ICHARM

Technical issues

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- How can we … ologic and geophysical … od forecasting … ins, especially in …
- …at kind of … *worldwide applicable"* … ery limited hydrologic & geophysical) in situ data availability?

Development of new effective tool to realize GFAS-Streamflow concept in developing countries:

"Integrated Flood Analysis System" (IFAS)

- Big necessity to prepare any **easy and efficient tool** just fit to the objective above, with **user-friendly** interfaces and **minimal cost** to implement?
- How should the system be to **sustain the effectiveness and reliability** of the implemented system under changing situations?

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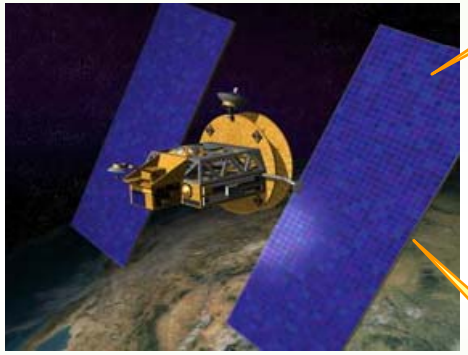
Original GFAS concept includes both rainfall alert and basin-scale flood forecasting using satellite information

Rainfall information

Heavy rain around the Upstream of ○○ River

Around the downstream of ○○ river

Observation satellite

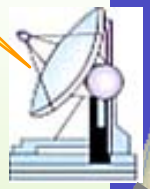


IFNet
International Flood Network

It is heavy rain in the upstream of XXX River.
There is a possibility to occur a flood in X hour.
Please evacuate to safe places

Flood Alert

Organization in charge of meteorology and disaster prevention



Ground stations

Raw Data

Flood Forecasting System

- Data for climate forecasts (real time/near real time data)
- Run-off calculation

Rainfall prediction, Flood prediction

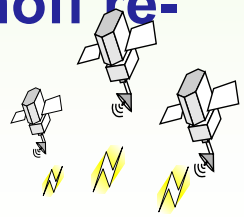
Directions to overcome technical issues (1/2)

< Global Flood Alert System (GFAS) – Streamflow >

- To acquire historical & real-time hydrologic information *anywhere in the world*

  → **Application of satellite-derived rainfall data and runoff re-analysis with those data**

  ex.) NASA-3B42RT (GFAS-rainfall), JAXA-Real-time GSMaP

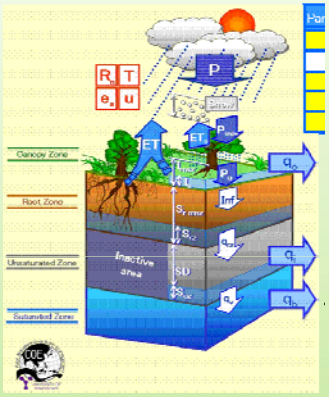


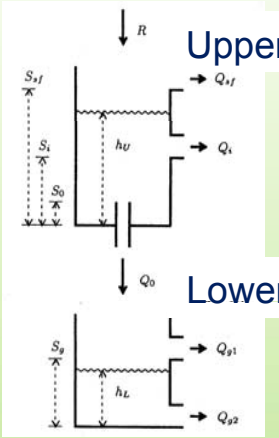
- To secure the availability of flood-runoff (hydrologic) model *anywhere in the world*

  →**Applying a practical & distributed-parameter hydrologic model, the parameters of which can be estimated on basis of globally available GIS data sets.**

  ex.) BTOP model,

  PWRI-PDHM Ver.2, etc.





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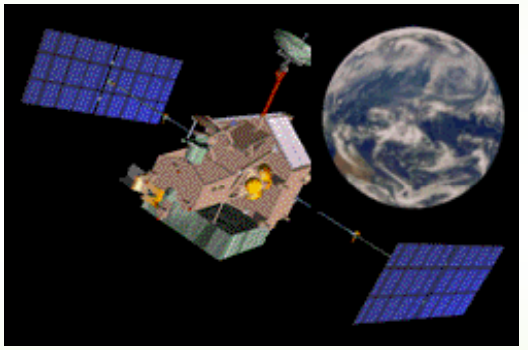
Example of satellite-based rainfall products

TRMM (Tropical Rainfall Measuring Mission) and 3B42RT

(1) Current System

- Launch of Tropical Rainfall Measuring Mission (TRMM) satellite in 1997
- Near real time data "3B42RT" since 2002 from TRMM, orbital satellites and geostationary satellites

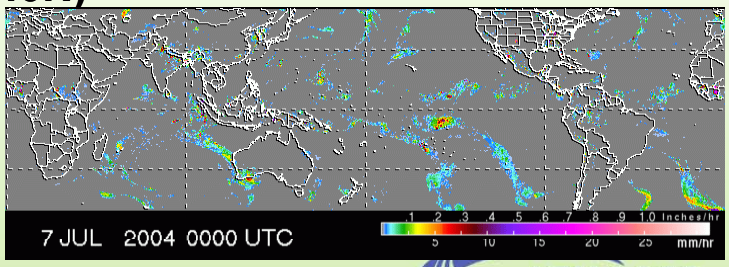


(2) Features

- 3-dimensional analysis of rainfall structure.
- No influence of topography.
- Global coverage including oceans

(3) Data Specifications of "3B42RT"

- Mesh Size: 0.25 degrees of latitude and longitude
  (rectangle of about 30km by 20km on 40N)
- Coverage Area: between 60N and 60S latitude
- Data Delivery: every 3 hours (not hourly)
  Near-real-time basis with several hours time lag



ftp://trmmopen.gsfc.nasa.gov/pub/merged/mergeIRMicro/

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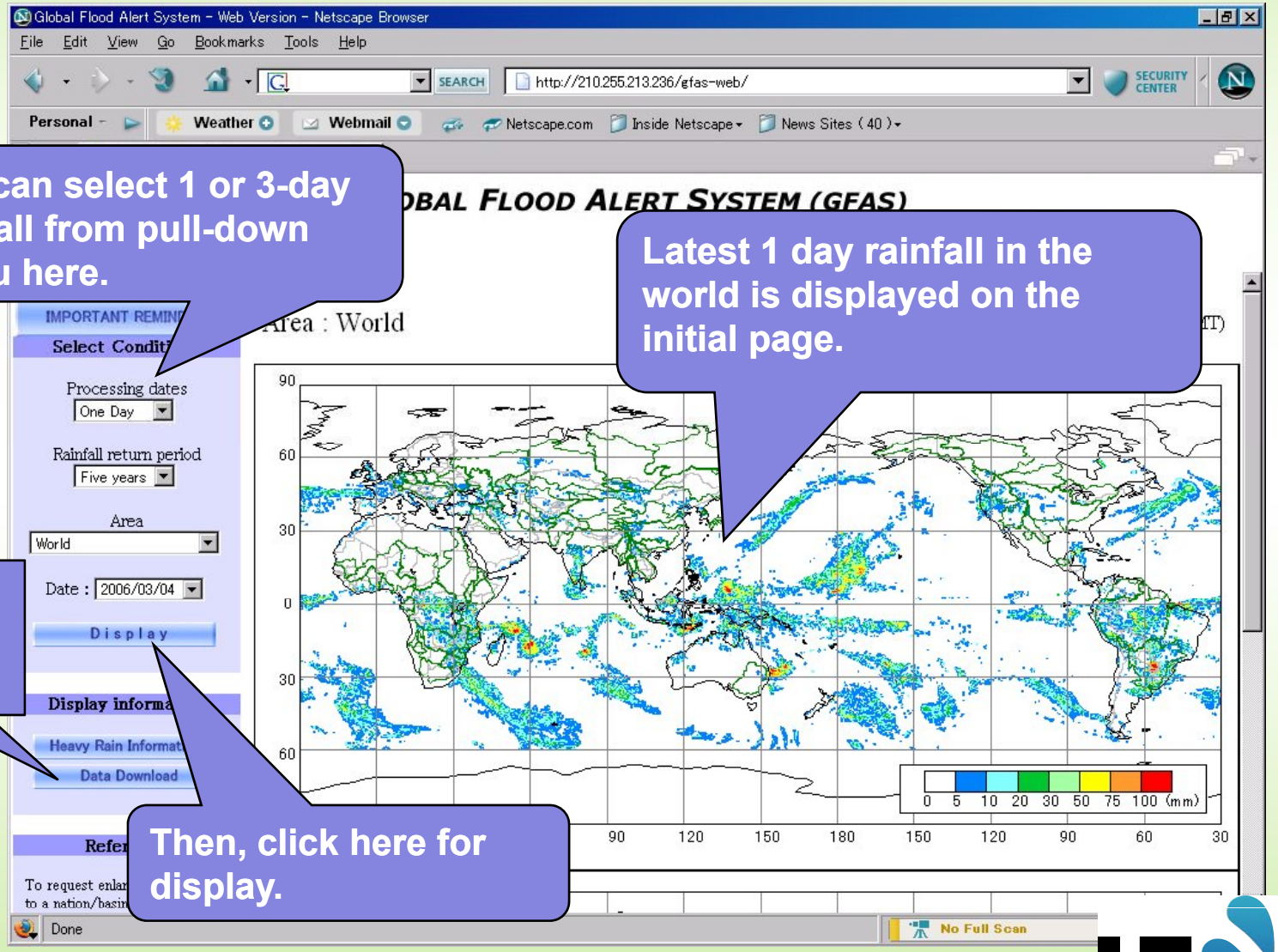
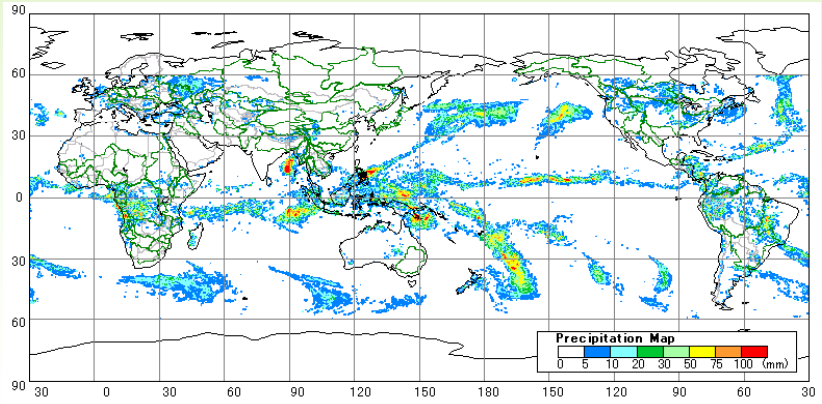
Global Flood Alert System (GFAS) – Rainfall by IFNet



http://gfas.internationalfloodnetwork.org/gfas-web/

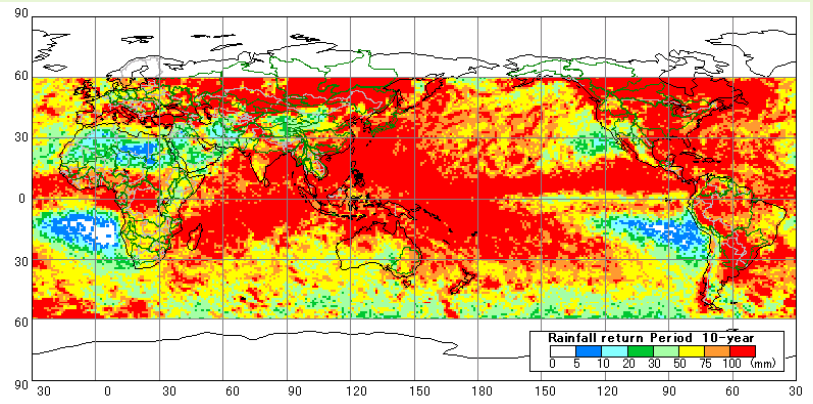
IFNet
International Flood Network

Contents of GFAS - Rainfall

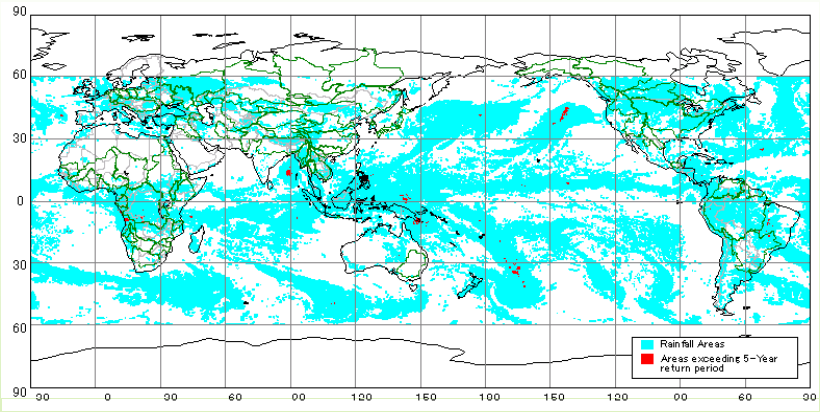


Real-time precipitation Map

(every 3 hour)



Pre-analyzed rainfall distribution exceeding 10-year return period



Real-time estimation of rainfall areas

Exceeding 10- (or 5-) Year Return Period

E-mail alarm for heavy rainfall

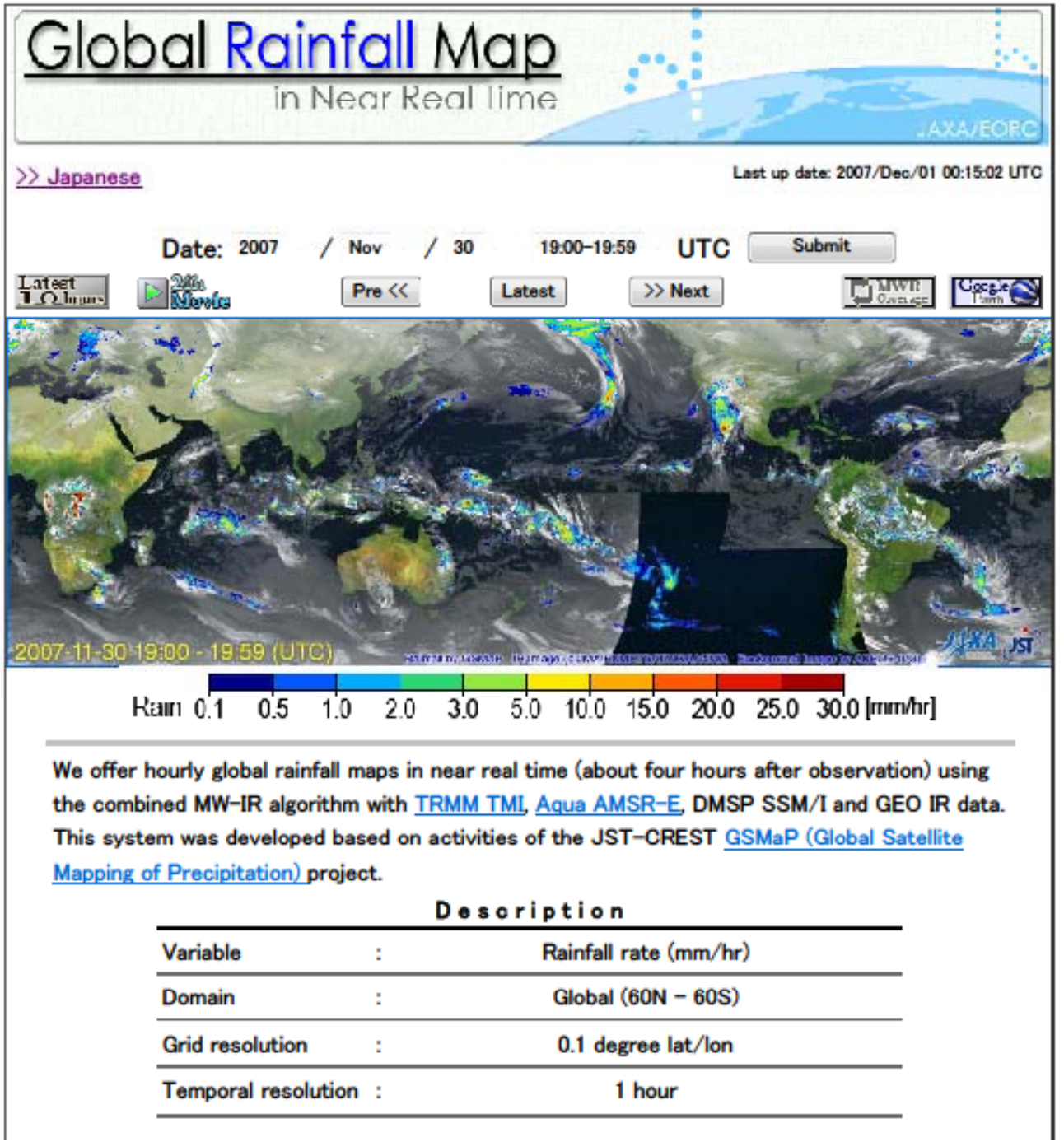
IFNet

International Flood Network

Real-Time GSMaP

JAXA,
JST-CREST
(Prof. Ken'ichi OKAMOTO,
Osaka Pref. Univ. et al.)

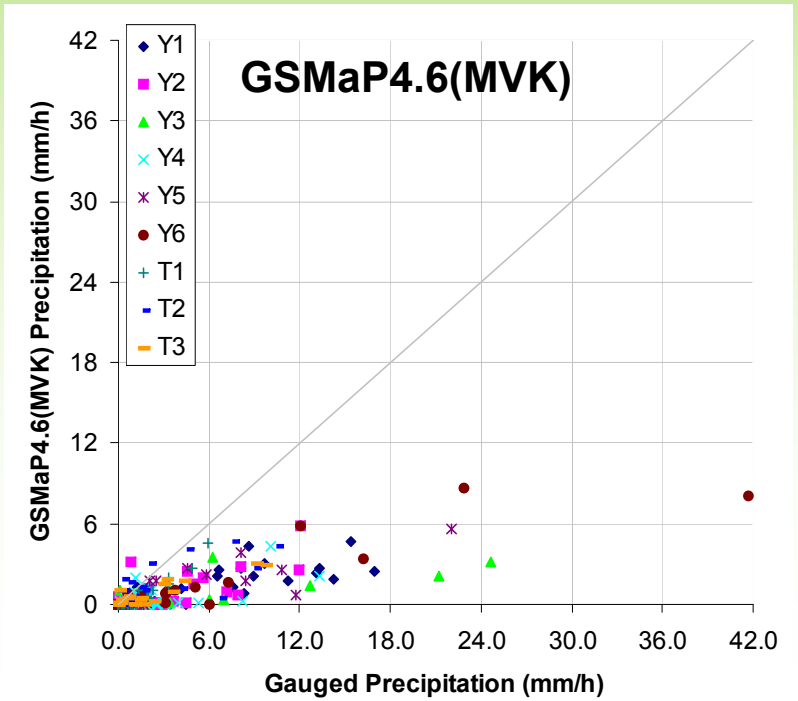
ICHARM/PWRI

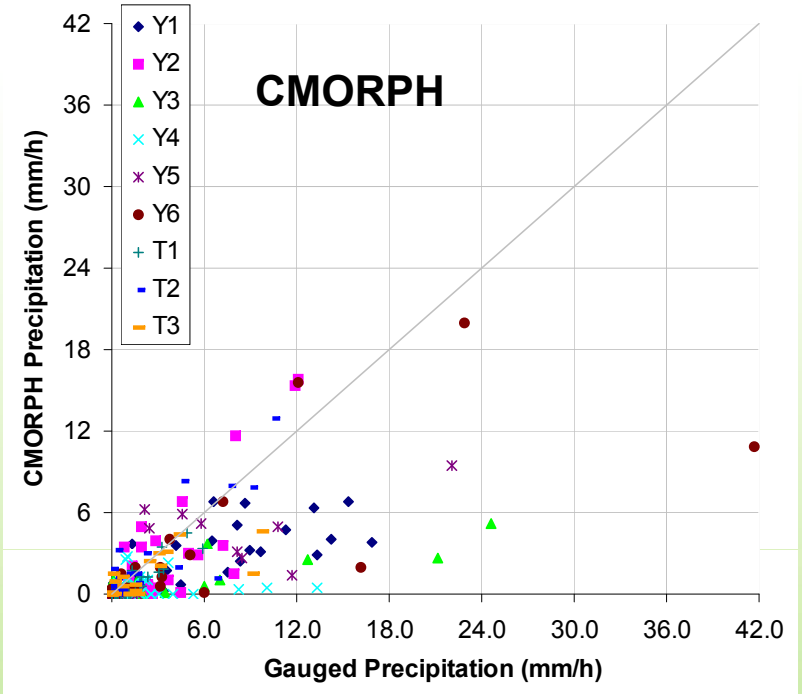


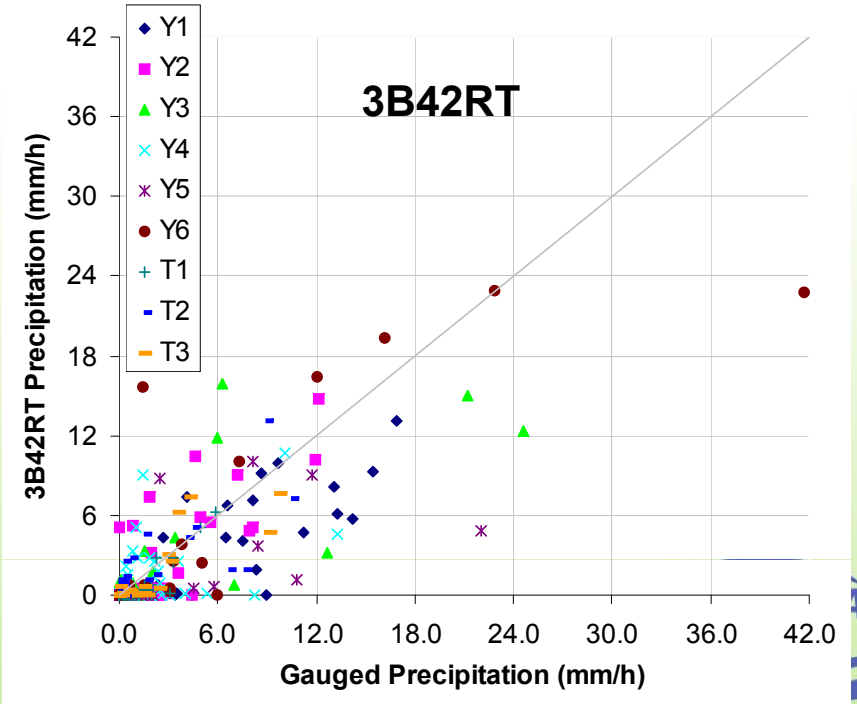
3h basin averaged rainfall data (mm/h)

For major storm events

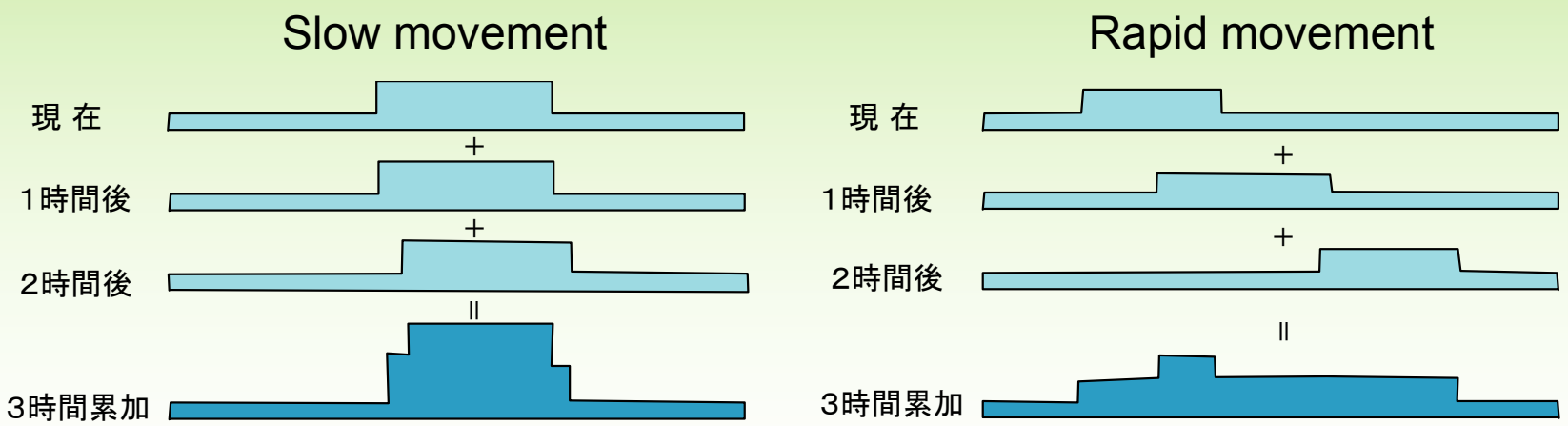
at Tone River & Yoshino River., Japan





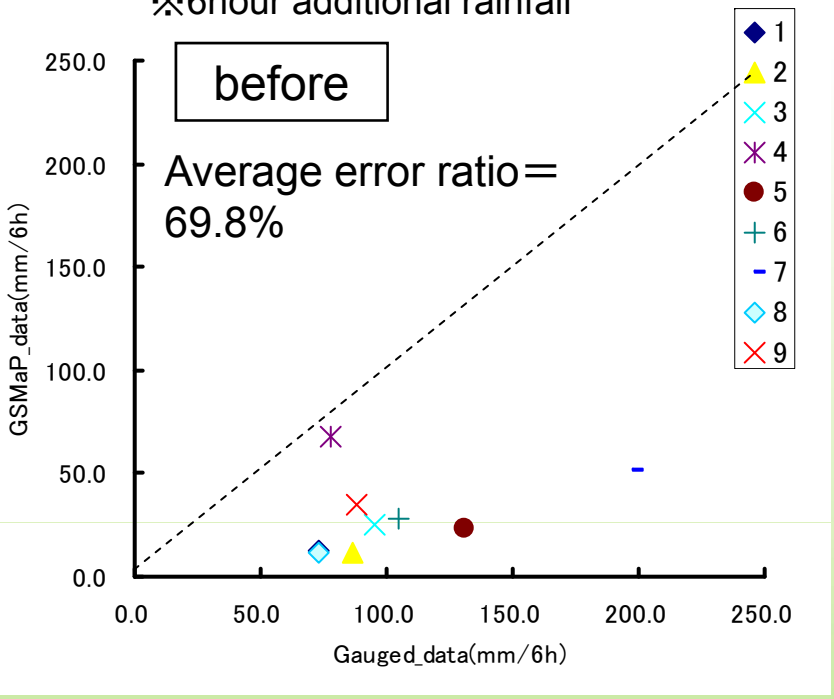


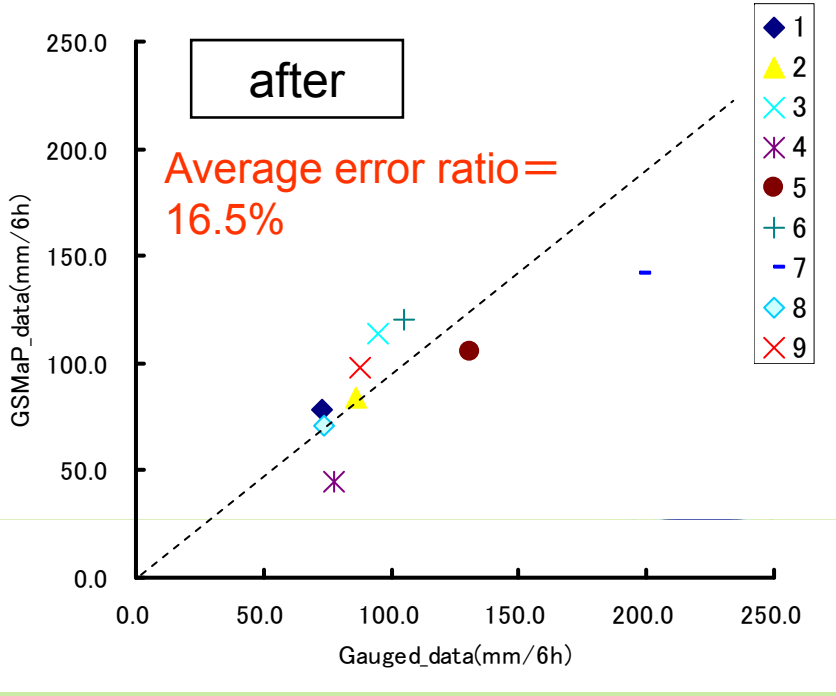
Developing of the correction method for satellite rainfall



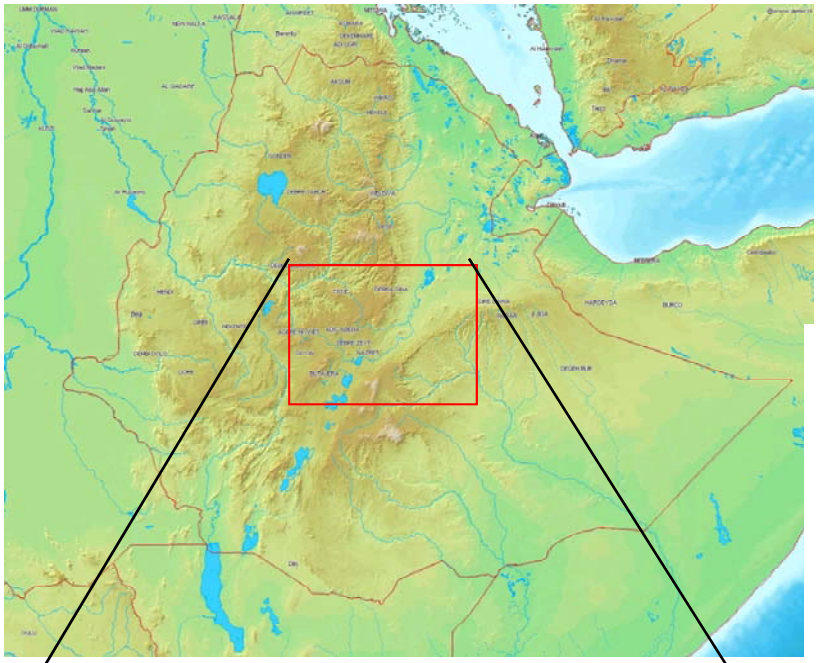
The proposal of the correction method considering rainfall movement !

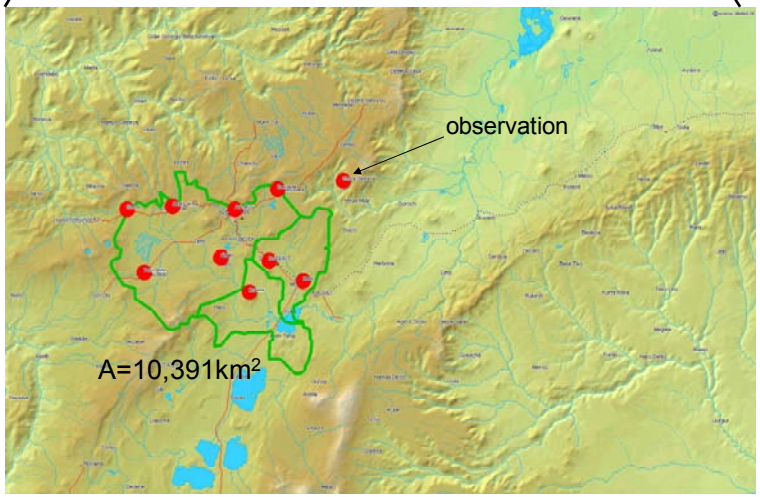
※6hour additional rainfall



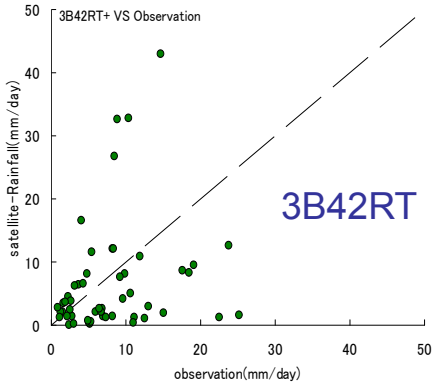


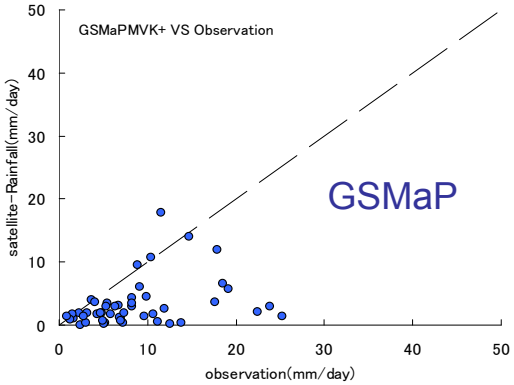
Verification in the Awash River Basin, Ethiopia

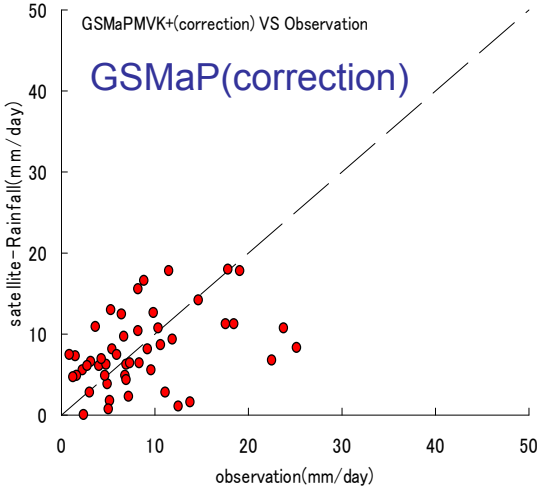




Daily rainfall during July and August of 2004







Global Precipitation Measurement
(GPM)

- Scheme for reports on global precipitation every 3 hours with main satellite and 8 constellation satellites
- Japan's contribution: Development of dual precipitation data and launch of H2-A Rocket

Core Satellite

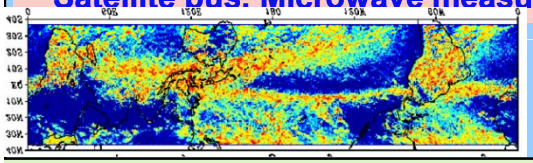
Dual-Frequency Radar
Multi Frequency Radiometer

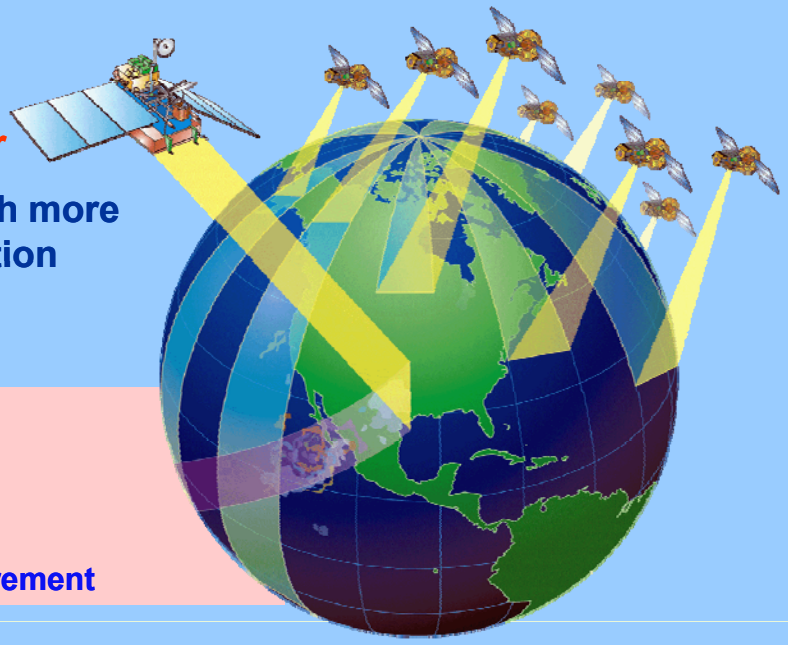
✧Observation of rainfall with more accuracy and higher resolution

✧Adjustment of data from constellation satellites

JAXA (Japan)
Dual-frequency radar, rocket

NASA(US)
Satellite bus. Microwave measurement



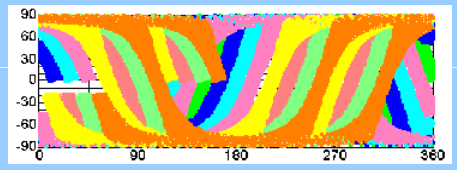


Constellation Satellites

Satellites with Microwave Radiometers

✧More frequent observation

Cooperation :
NOAA(US),NASA(US),ESA(EU), China, Korea and others



Earth heating phenomena
Study of climate change
Improvement of forecasting system

Global Observation every 3 hours

IWRM
Flood forecasting
Forecasting of crop productivity

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Directions to overcome technical issues (2/2)

< Integrated Flood Analysis System (IFAS) >

～To realize the concept of GFAS – Streamflow ～

For local engineers in developing countries

- **To enable the implementation of flood forecasting system with global real-time satellite-based rainfall data and other GIS databases, without much cost and a priori high-tech capacity, *anywhere in developing countries*, and**
- **To enable *local engineers* to easily improve the accuracy and reliability of the system by combining *with in-situ local data***

  → **User-friendly interfaces using state-of-the-art technology, including modules to use satellite-based data and to analyze GIS data for building hydrologic models**

- **To enable local administrators and engineers to utilize IFAS effectively by themselves with the sense of local ownership.**

  → **Both technical training and dissemination activities are jointly promoted**

Developing countries can utilize advanced technology as easily, effectively and autonomously as possible with the sense of local ownership

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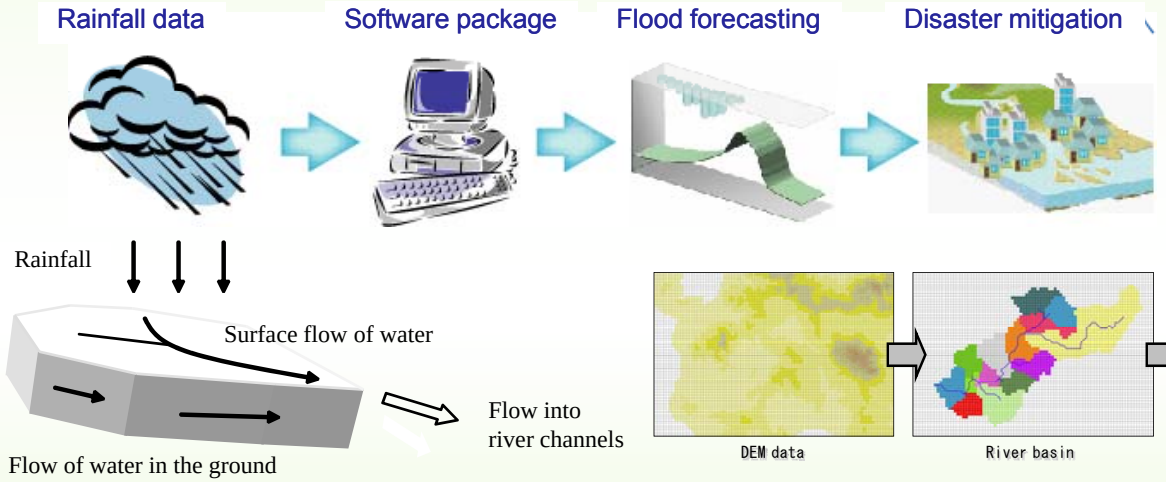
Development of IFAS for flood runoff analyses on a river basin scale

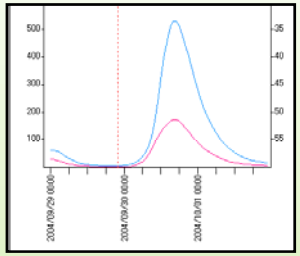
- IFAS (Integrated Flood Analysis System)

  The software package for the flood runoff analysis equipped with GUI



- Developed by joint research (FY2005-2007)

  ICHARM / Public Works Research Institute (PWRI),
  Infrastructure Development Institute (IDI / Secretariat of IF-Net),
  and nine major civil-engineering consulting companies



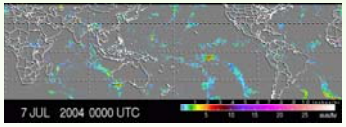
- Distribution of executables, free of charge

Global Flood Alert System (GFAS) - Streamflow

- Toward prompt implementation of flood forecasting / warning systems with the sense of ownership of local users in developing countries -

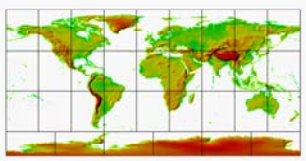
Global observation of rainfall by earth observation satellites

Satellite-based near real-time rainfall data

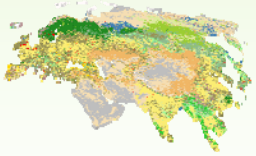


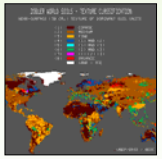
Ex.) IFNet-GFAS, NASA-3B42RT, JAXA-GSMaP

Topographic data

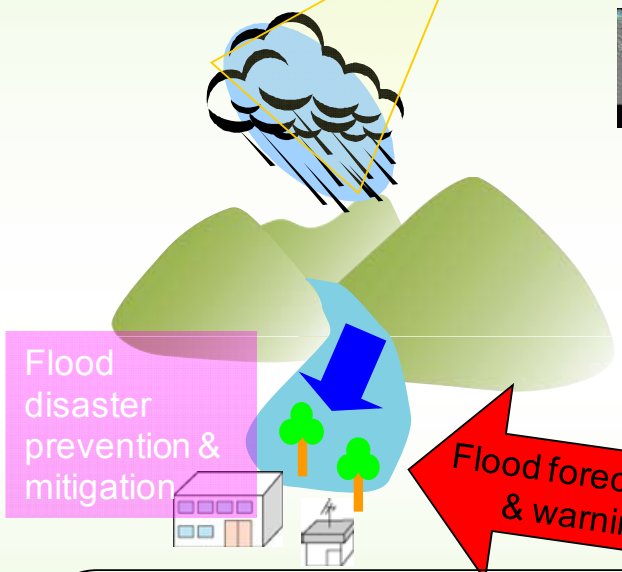


Other GIS data for runoff mode (Land use, soil, etc.)





Data download through Internet, free of charge

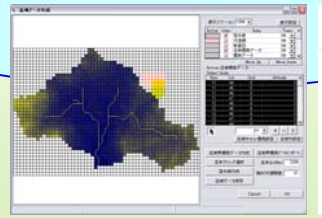


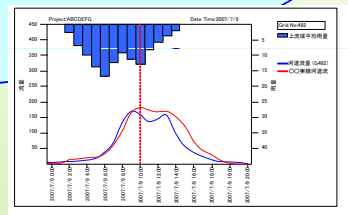
Flood disaster prevention & mitigation

Flood forecasting & warning

IFAS *(A basis for flood forecasting/warning system)*

Real-time input: Satellite & ground rainfall
GIS data input for setting parameters
GIS analysis to build runoff model
Runoff analysis and flood simulation
User-friendly interfaces for output





Current situation

Despite of the needs for flood forecasting/warning,
No rainfall, GIS data, nor analytical tools
→ Required much money & time for implementation

After the application of IFAS:

Prompt & efficient implementation
No need to develop original core system
Step-by-step improvement of accuracy with hydrological observational network

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Plan to promote the implementation of flood forecasting system using GFAS-Streamflow with IFAS

- **First Phase (- FY2008)**
  - To implement the method to utilize newest global satellite-based rainfall products with auto-correction algorithm for heavy rainfall
  - To implement the method to utilize global climatic and geophysical datasets available through the Internet
  - To implement the method to utilize state-of-the-art numerical weather forecast and hydrologic modeling technology with GIS analytical tools
  - Effective dissemination of flood forecasts and warnings with universal and graphical visualization

    → Realization of flood forecasting and warning system even in poorly-gauged river basins

- **Second Phase (FY2008 -)**
  - To implement the method to improve the performance of the flood forecasting system by the integration with local in-situ hydro-meteorological data
  - To implement the method to attain higher accuracy and efficiency of numerical weather prediction and hydrologic simulation models
  - To make the IFAS system compatible with universal platforms such as CommonMP, OpenMI, MMS, etc.
  - To hold educational and training seminars and workshops for local administrators/engineers on the theoretical background, usage and maintenance of the IFAS
  - To enhance local pilot studies

- **Third Phase (FY2009 -)**
  - Consultation and/or proposal on the arrangement of meteo-hydrological in-situ observation network and flood forecasting system, the improvement of the system, alternatives for flood control and/or integrated flood management, etc. on the basis of experiences of local pilot studies

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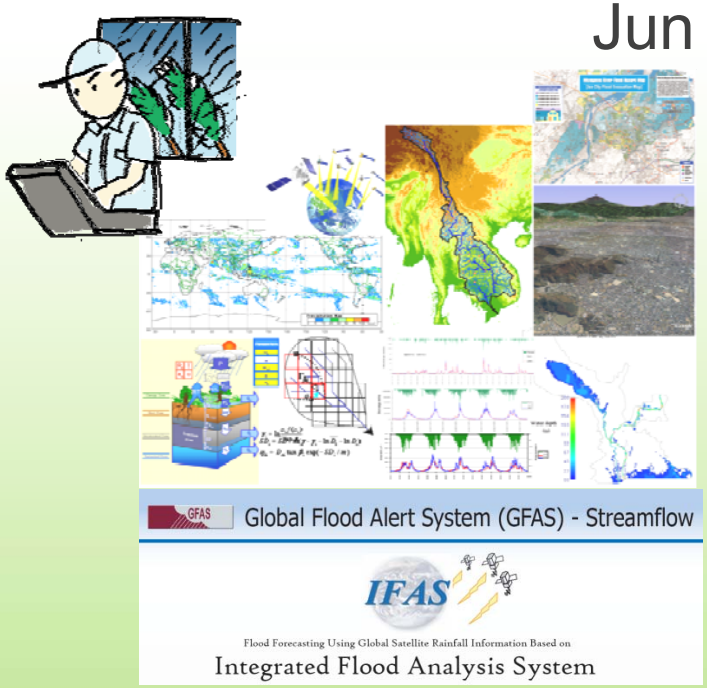
Technology for Flood Forecasting System

-Major features and functions of IFAS for poorly-gauged river basins –

International Center for Water Hazard and Risk Management

under the auspices of UNESCO（ICHARM）hosted by PWRI

Jun MAGOME



United Nations Educational, Scientific and Cultural Organization

PWRI

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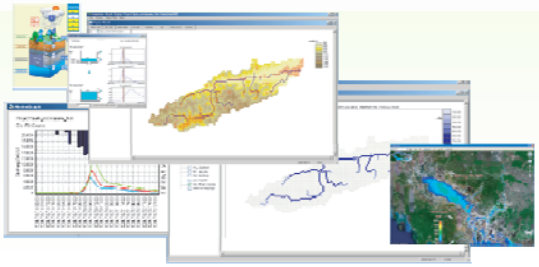
IFAS

Flood Forecasting Using Global Satellite Rainfall Information Based on

Integrated Flood Analysis System



-- Key Features --

1. Utilization of ***satellite-based rainfall***
2. ***Multi*** run-off analysis ***engines***
3. ***Automatic*** model creation
4. ***Visualization*** of flood forecasting results
5. ***Free*** distribution

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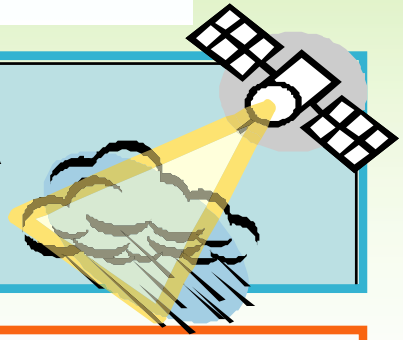
IFAS

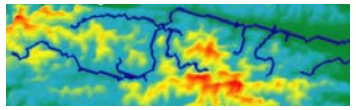
Rainfall data

Satellite-based rainfall data
Ground-based rainfall data



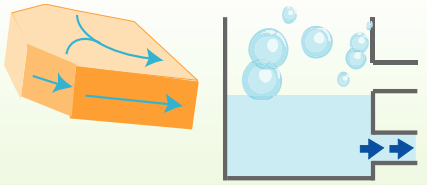
Modeling

Creation of a river channel
Estimation of parameters

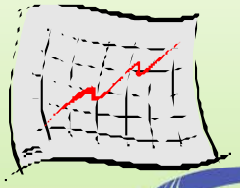


Runoff analysis

Distributed model
BTOP model



Display of results



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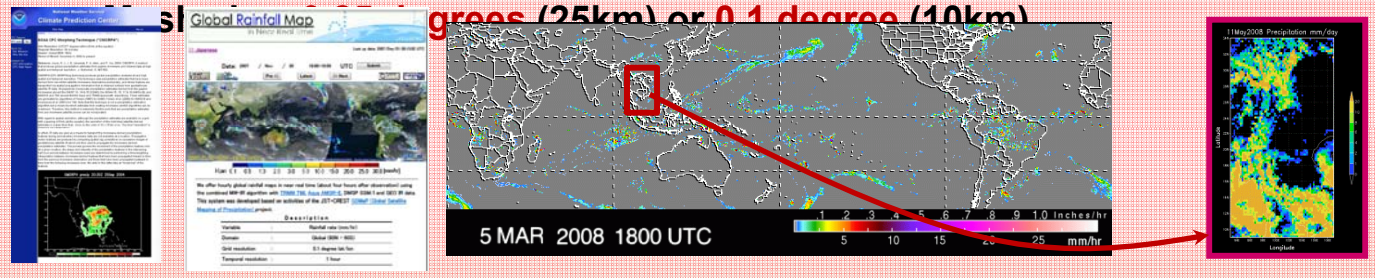
Rainfall Data : Current Functions

1) Satellite-based rainfall data

- TMPA-3B42RT (NASA)
- QMORPH/CMORPH (NOAA)
- GSMaP (JST/CREST, OPU,JAXA etc.)

Global coverage : between 60N-60S latitude

Hourly, 0.25 degrees (25km) or 0.1 degree (10km)

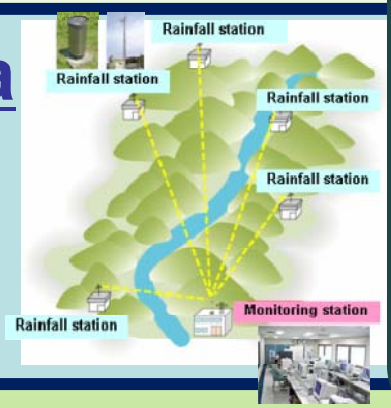


Automatic Data Extraction for area of interest

Provided by NASA, NOAA, JAXA and IFNet-GFAS through the Internet for free

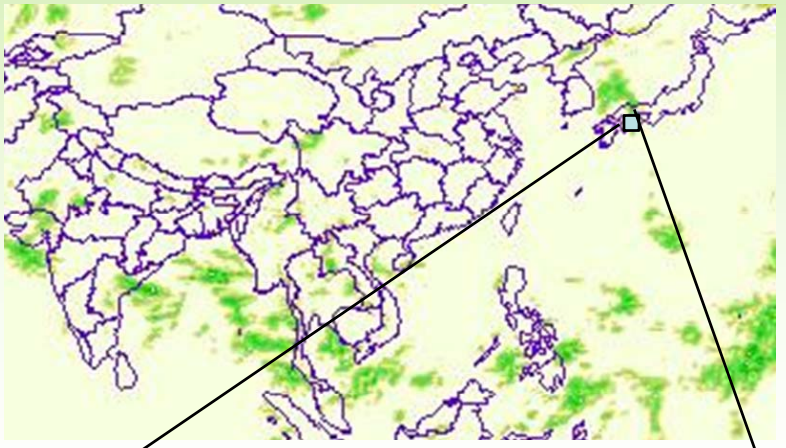
2) Ground-based rainfall data

- Observed Own data
  (Local Ownership)

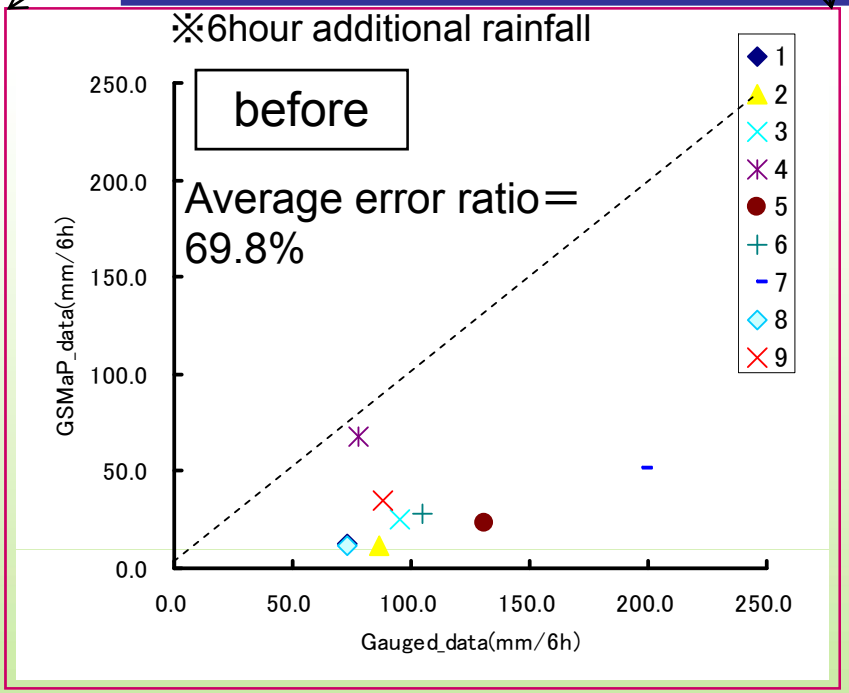


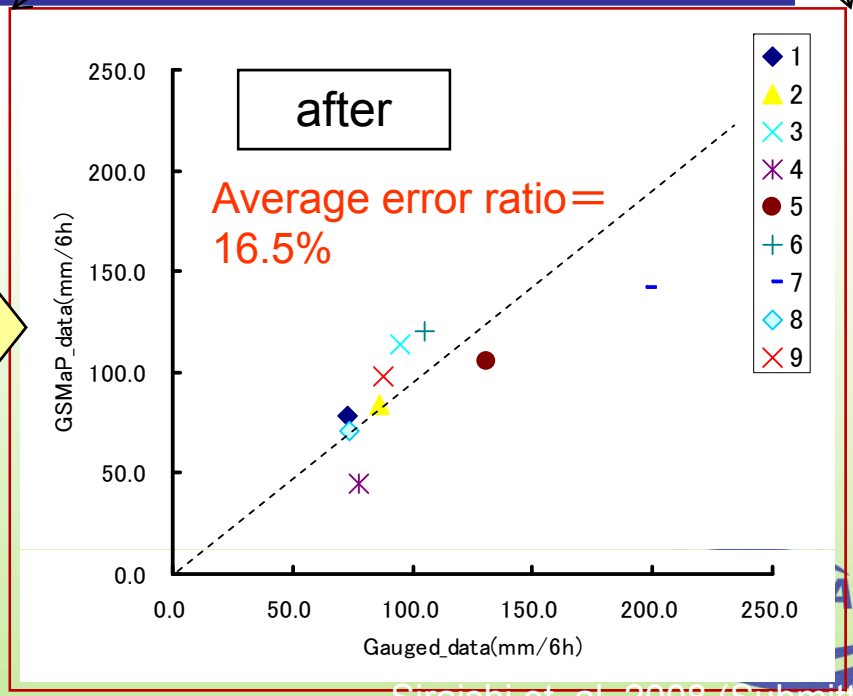
3) Integration
(Correction of Rainfall)

Rainfall Data : Rainfall Correction



Key : rainfall movement



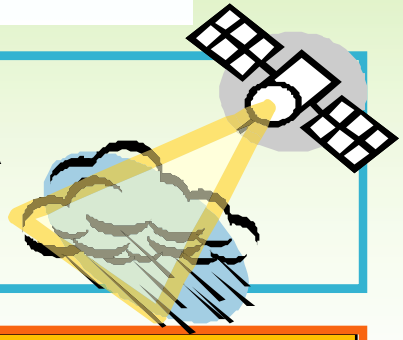


Siraishi et. al, 2008 (Submitted)

IFAS

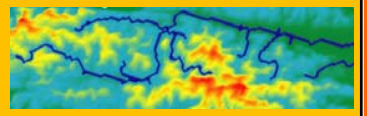
Rainfall data

Satellite-based rainfall data
Ground-based rainfall data



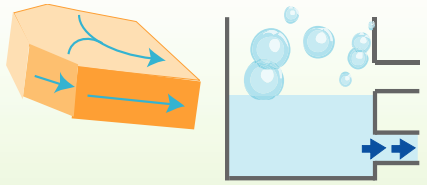
Modeling

Creation of a river channel
Estimation of parameters

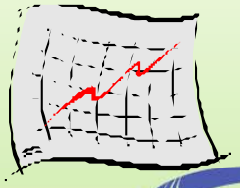


Runoff analysis

Distributed model
BTOP model



Display of results



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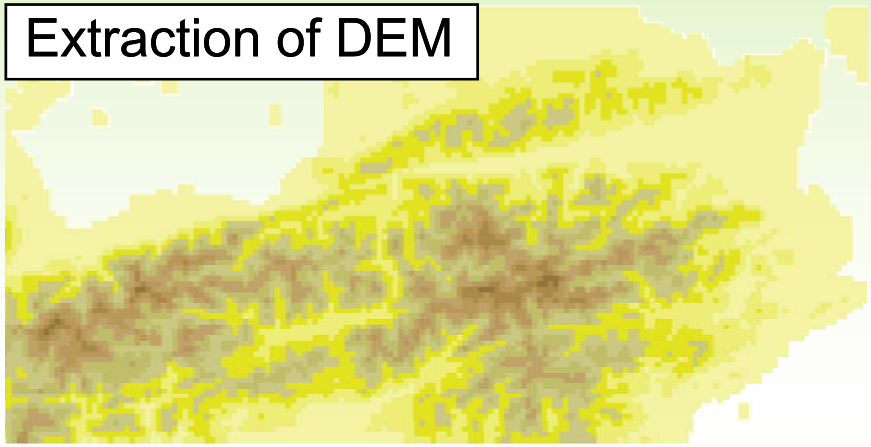
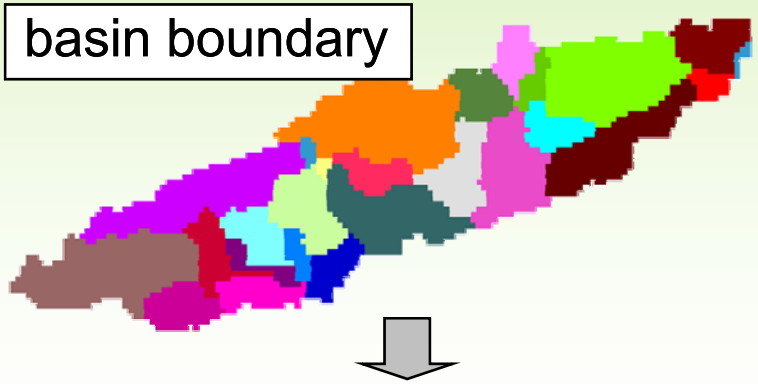
Modeling

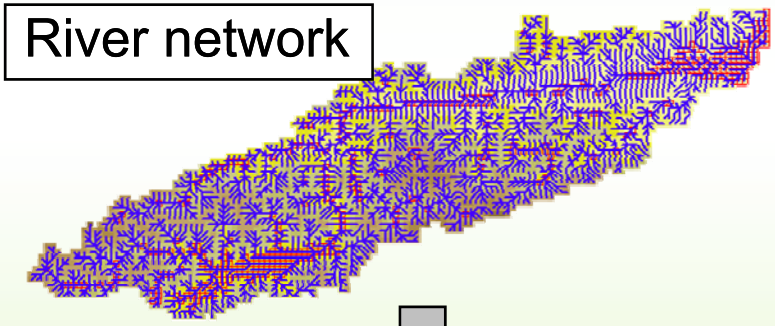
Extraction of DEM



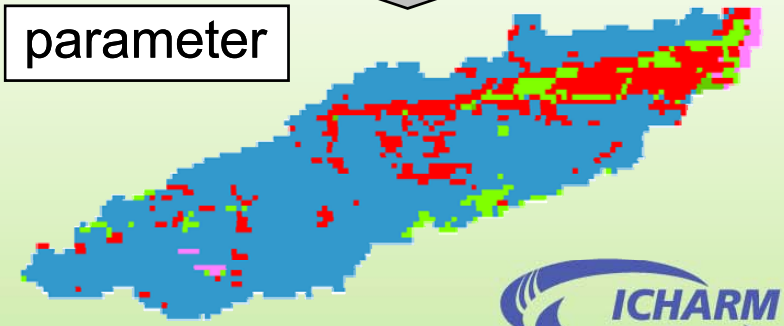
basin boundary



River network



parameter



Land Cover Classification (GLCC)	IFAS Classification
Urban and Built-Up Land	Urban area
Dryland Cropland and Pasture	Wetland
Irrigated Cropland and Pasture	
Mixed Dryland/Irrigated Cropland and Pasture	
Cropland/Grassland Mosaic	Grassland
Cropland/Woodland Mosaic	
Grassland	
Shrubland	
Mixed Shrubland/Grassland	
Savanna	
Deciduous Broadleaf Forest	Forest
Deciduous Needleleaf Forest	
Evergreen Broadleaf Forest	
Evergreen Needleleaf Forest	
Mixed Forest	
Water Bodies	Water Bodies
Herbaceous Wetland	Wetland
Wooded Wetland	
Barren or Sparsely Vegetated	Grassland
Herbaceous Tundra	
Wooded Tundra	
Mixed Tundra	
Bare Ground Tundra	
Snow or Ice	Water Bodies

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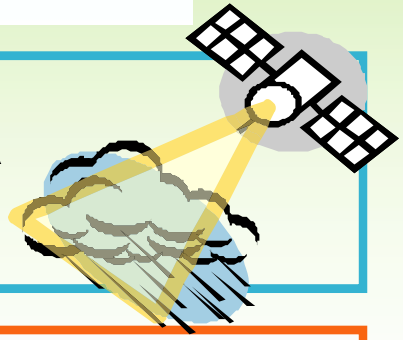
"Automatic" **Model creation & parameter estimation**

IFAS

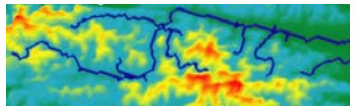
Rainfall data

Satellite-based rainfall data
Ground-based rainfall data



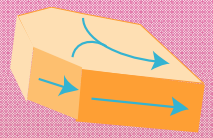
Modeling

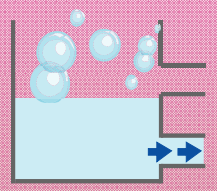
Creation of a river channel
Estimation of parameters



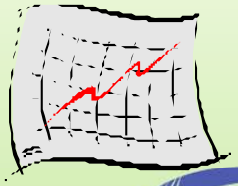
Runoff analysis

Distributed model
BTOP model





Display of results



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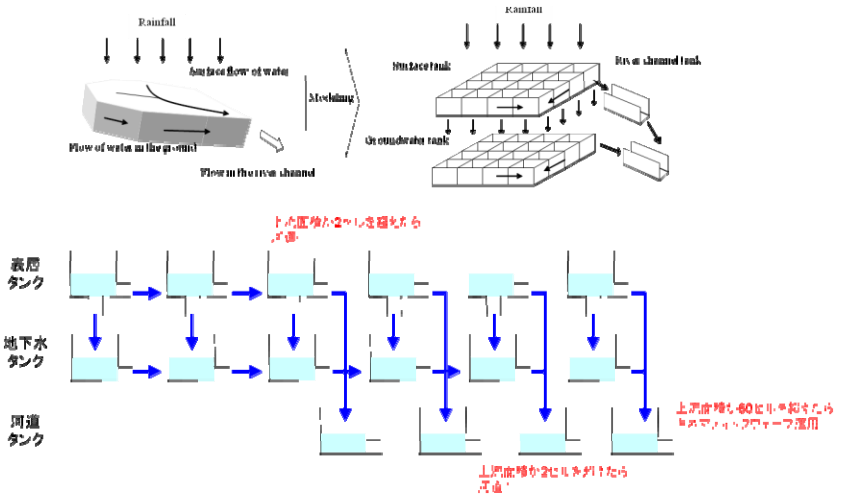
Runoff Analysis

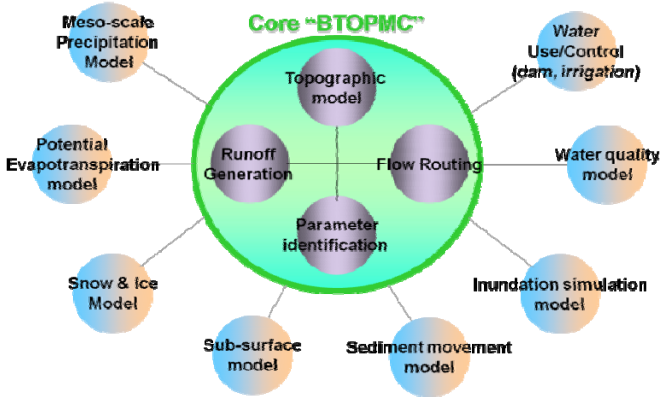
PWRI-Distributed Hydrological Model (PDHM) Suzuki et.al, 1996 ~ Ver. 2.0



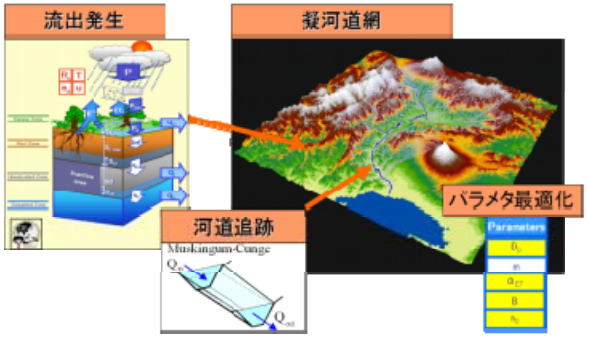
- Easy parameter calibration
- Developed and tested at many basins
- Jointly Developed

International Centre for Water Hazard and Risk Managemennt (ICHARM)
Public Works Reserch Institute (PWRI)
CTI Engineering Co., Ltd.
NIPPON KOEI Co., Ltd.
IDEA Consultants, Inc.
Yachiyo Engineering Co., Ltd.
Pacific Consultants Co., Ltd.
Tokyo Kensetsu Consultants Co., Ltd.
NEWJEC Inc.
CTI Engineering International Co., Ltd.
Infrastructure Development Institute (IDI)
Kokusai Kogyo Co., Ltd.

YHyM/BTOP Model Ao et. al, 1998 ~ Ver. 1.4 (Coming Very Soon)



Core module and Multi-Module



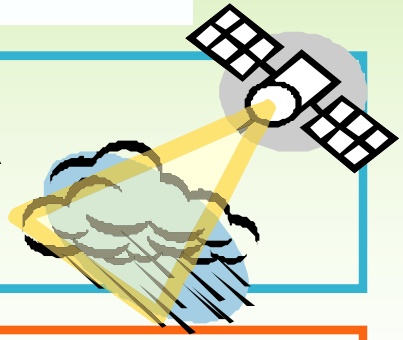
Applied well more than 100 river basins

Multi Runoff Analysis Engine

IFAS

Rainfall data

Satellite-based rainfall data
Ground-based rainfall data



Modeling

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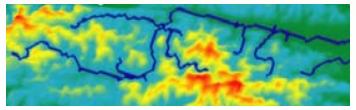
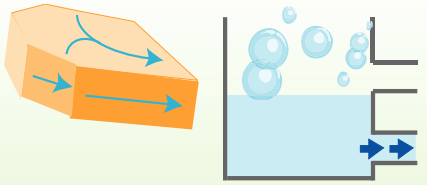
Estimation of parameters



Runoff analysis

Distributed model
BTOP model



Display of results

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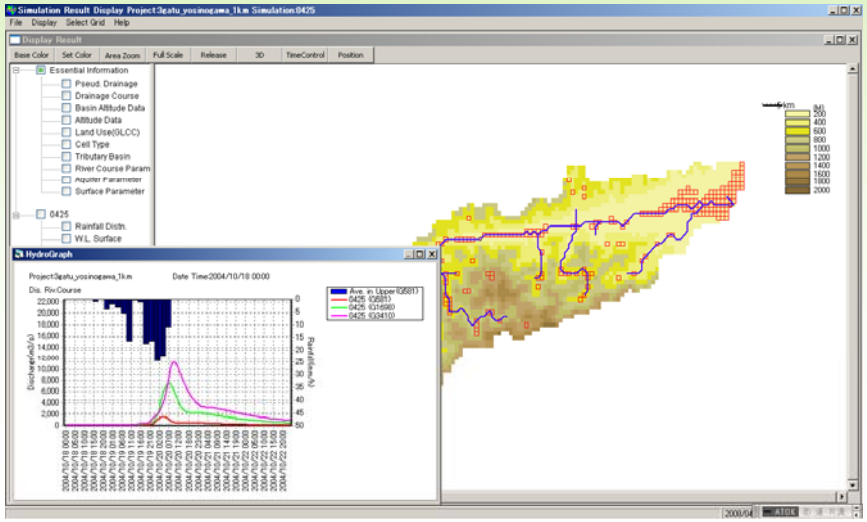
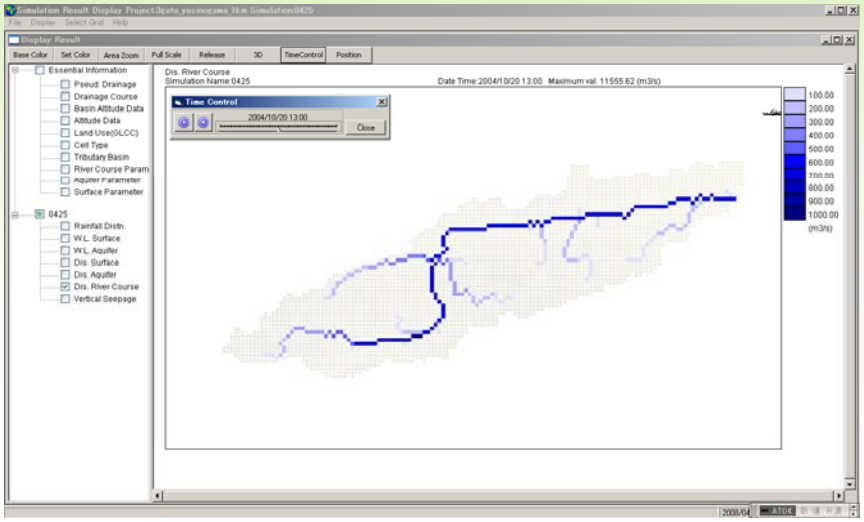
Display Results (IFAS-PDHM)

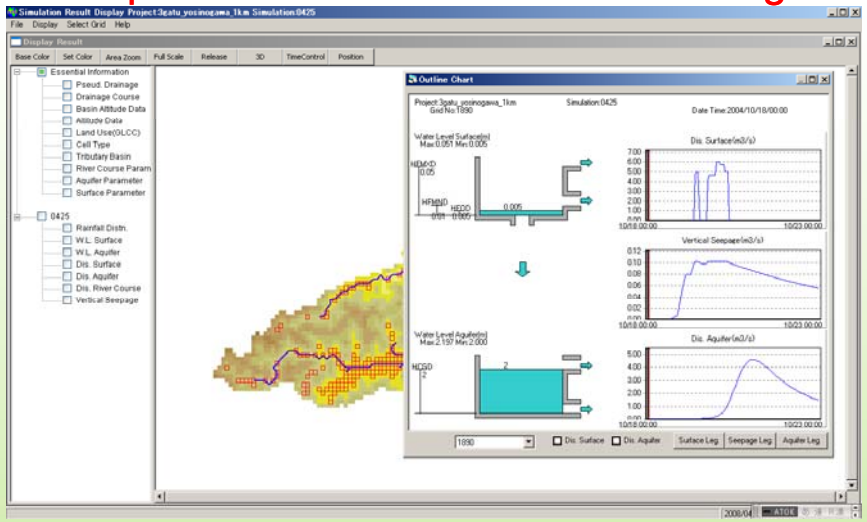
Hydro-graph



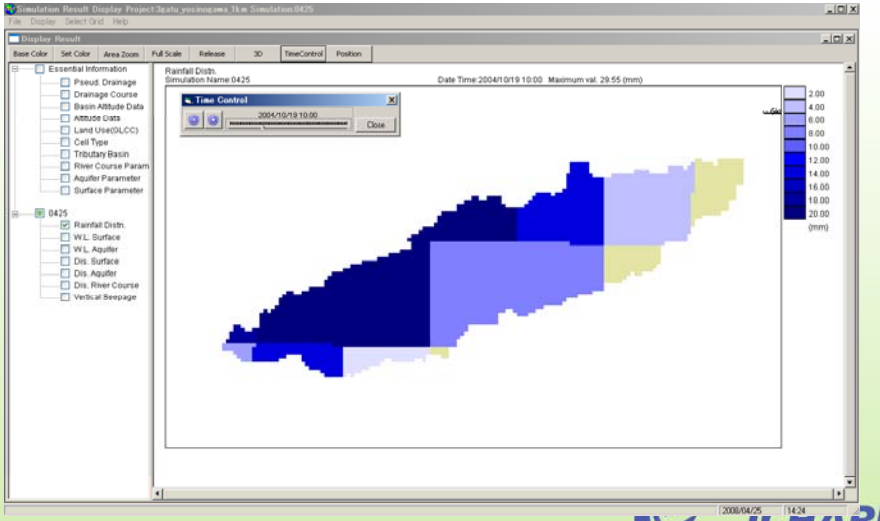
Plan view of river discharge



Graph of tank water level and discharge

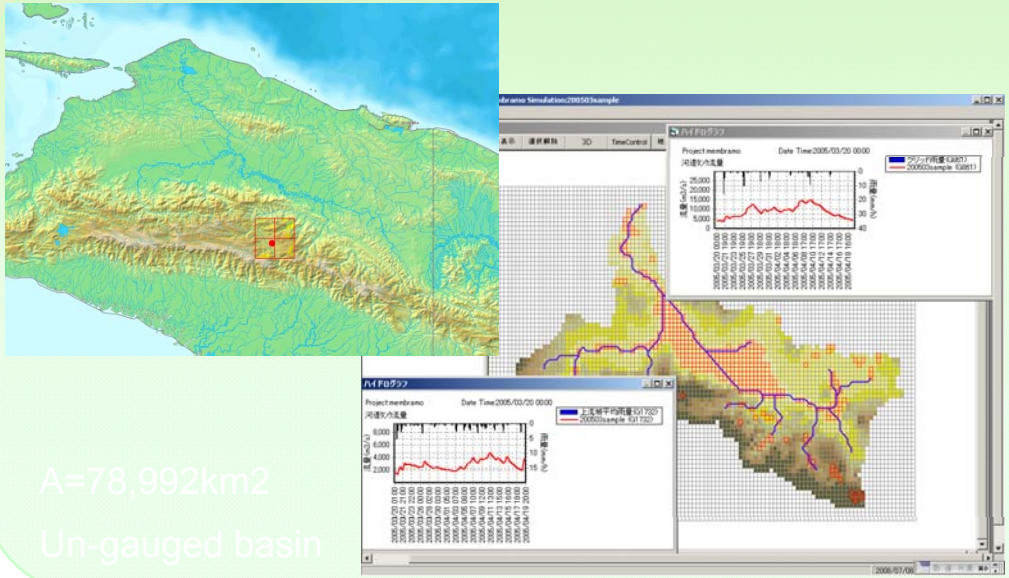


Plan view of satellite-based rainfall



Display Results (IFAS-PDHM)

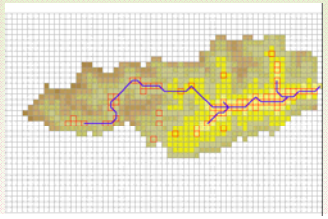
Mambermo River Basin in Republic of Indonesia



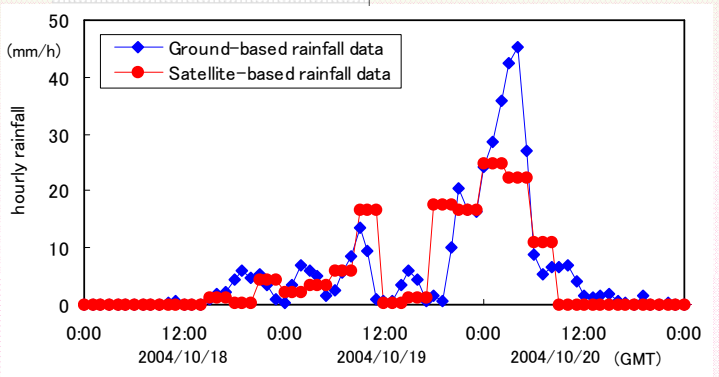
A=78,992km2

Un-gauged basin

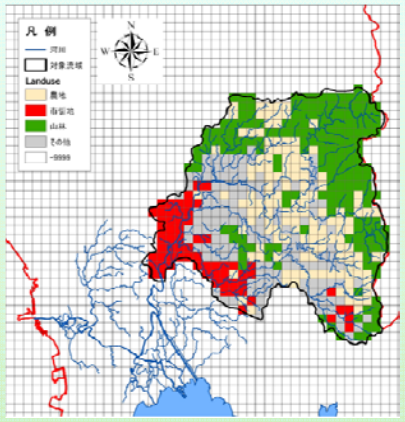
Sameura dam River Basin in Japan



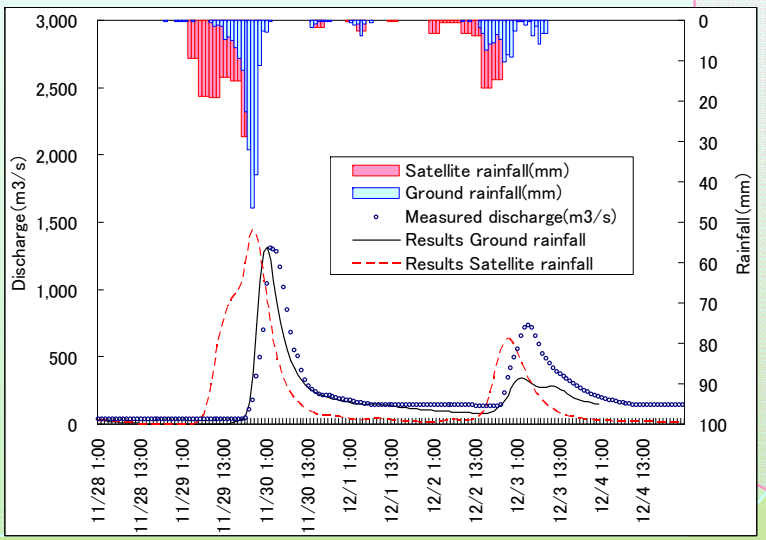
A=472km2

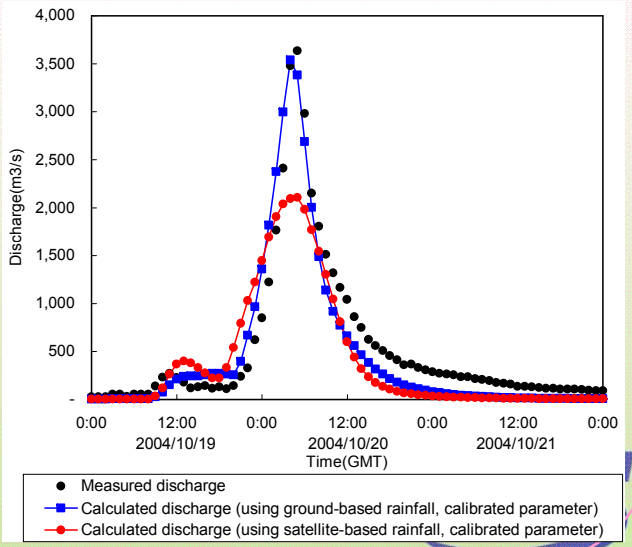


Pasig River Basin in Republic of the Philippines



A=499km2





Further Development for poorly-gauged basins

- "***Satellite-based rainfall corrections***"
  with/without ground-based rainfall data
- ***Real-time*** flood forecasting
- Integration of ***flood inundation model***
- ***Enhanced Visualization*** using freeware (Google Earth/Map)
- Incorporation of numerical weather forecast
  ex.) Global forecast with 20km-mesh by JMA
- Consideration on uncertainty of forecasting
  Ensemble forecast
- Statistical analysis tools to identify flood risks
- Downscale technology for hydrologic forecasting
  ex.) Weather Research and Forecasting (WRF) Model)

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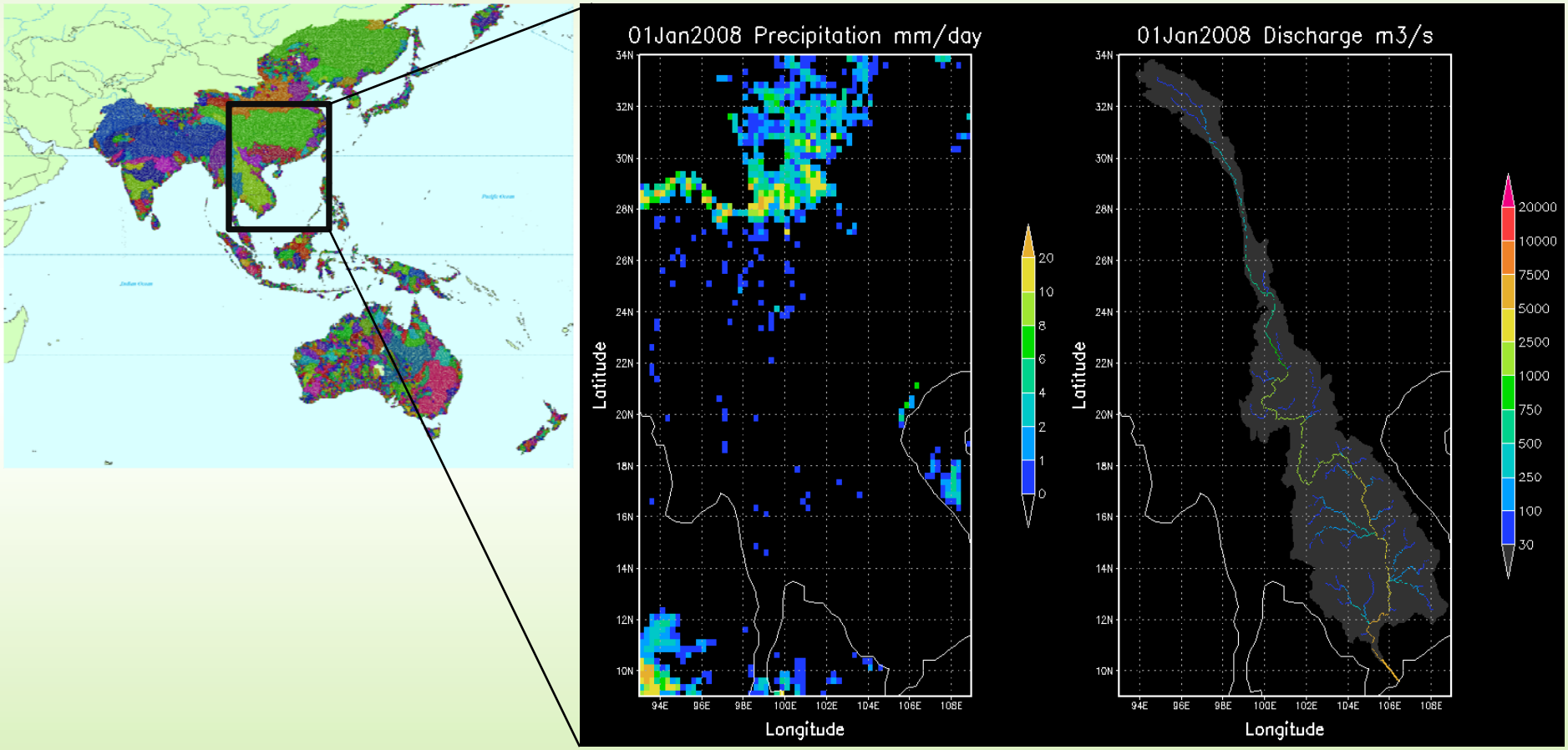
“Real-time” Flood Alert System at Anywhere



Example : BTOP Model + TMPA 3B42RT

Magome, 2008

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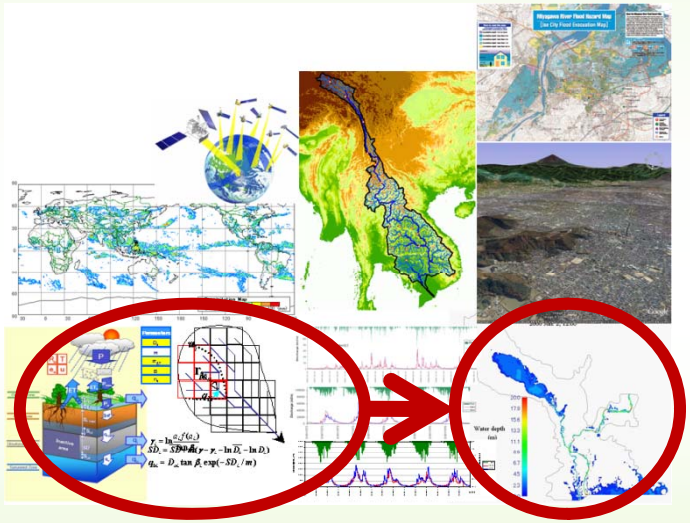
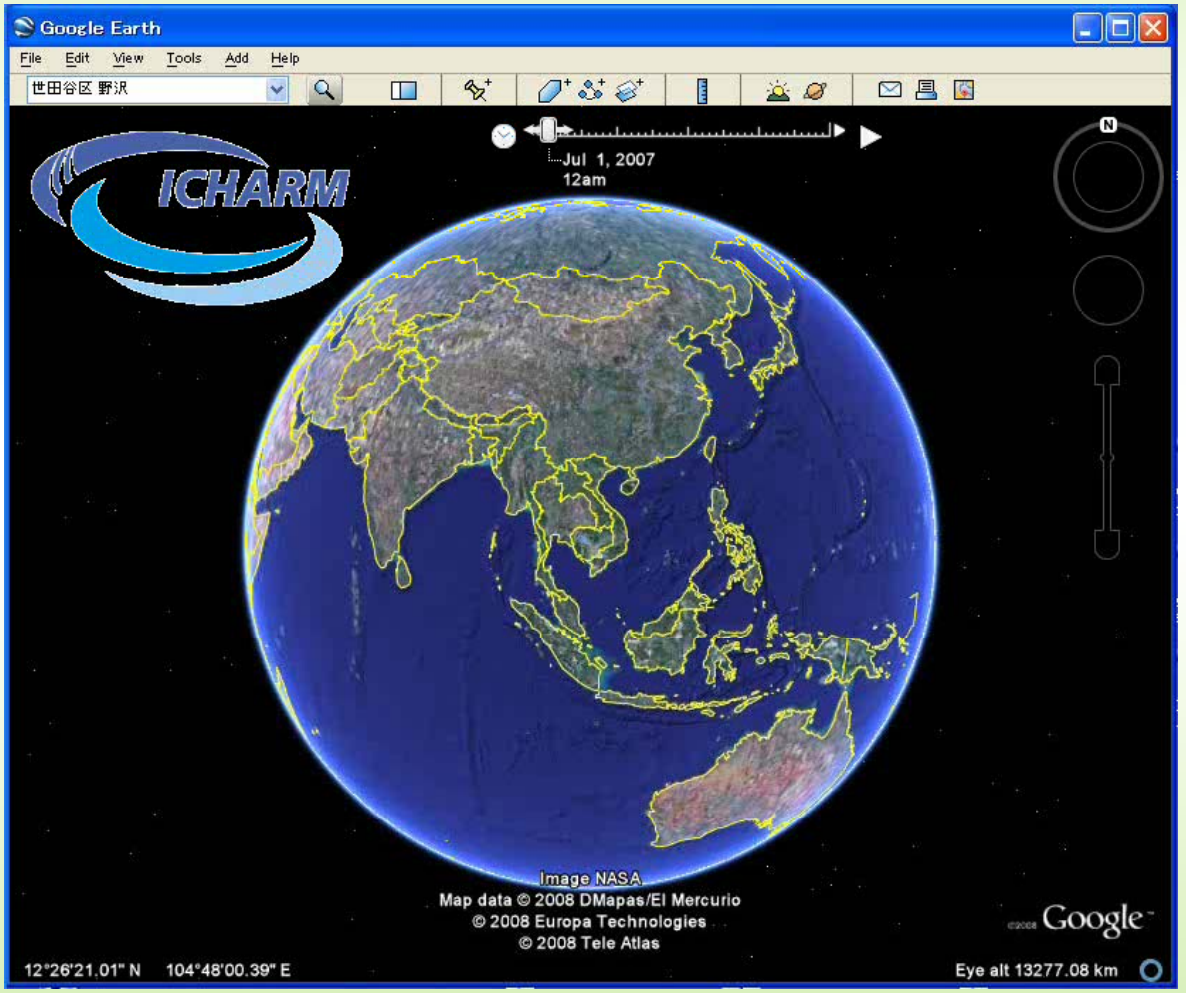
Integration of “Flood Inundation Model” to Distributed Hydrological Model





Hai, Magome, 2008

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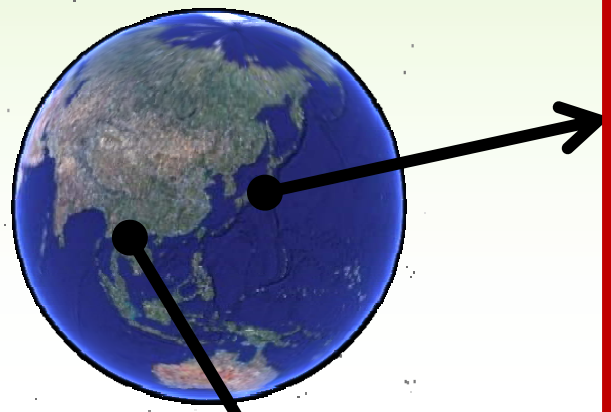
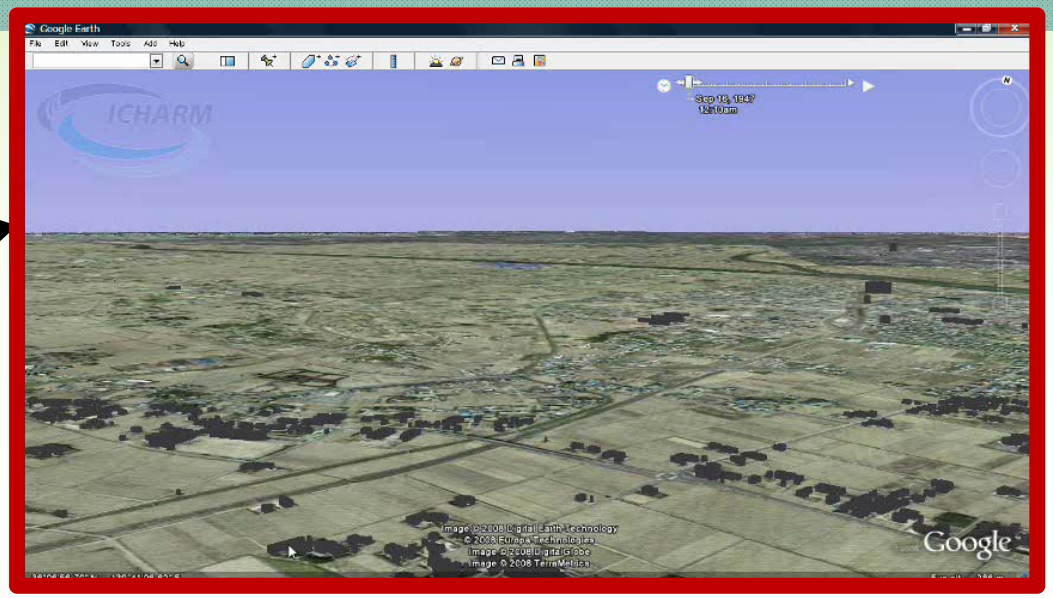
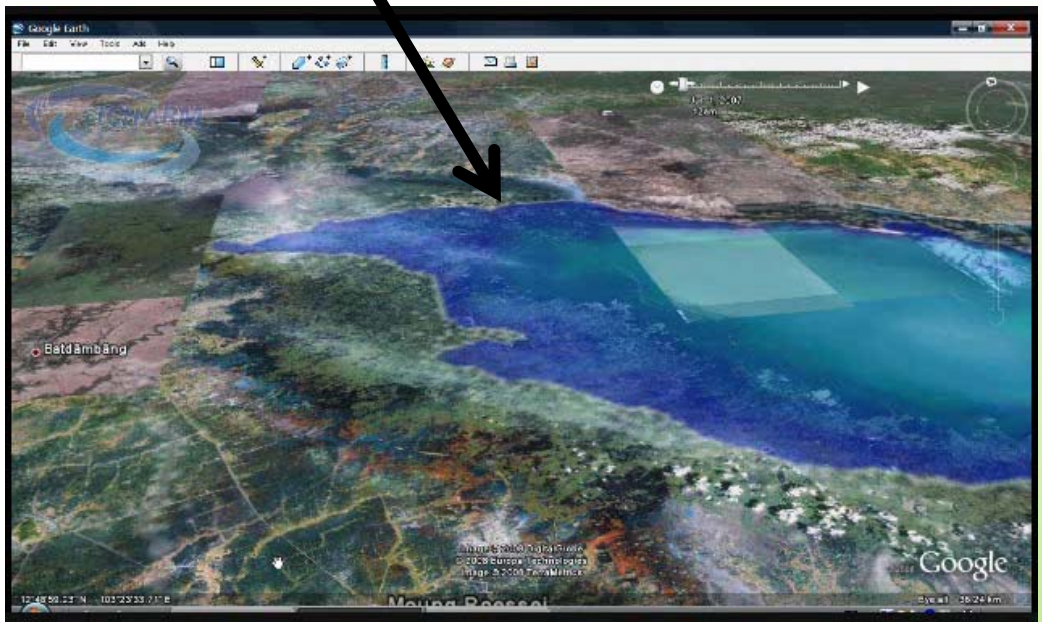
Enhanced & Easy Visualization







Tone River (Japan) analysis

for case of levee breach in Tokyo Area

Hai, Magome, 2008

Lower Mekong River Basin

(Zoom : Northwest of Tonle Sap Lake)

ICHARM

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International Centre for Water Hazard and Risk Management (ICHARM)
under the auspices of UNESCO

http://www.icharm.pwri.go.jp/ September 2008

Thank you very much