

River information management and flood forecasting in Japan



Tomonobu SUGIURA

**Senior Researcher
Hydrologic Engineering Research Team
International Centre for Water Hazard and Risk Management (ICHARM)**

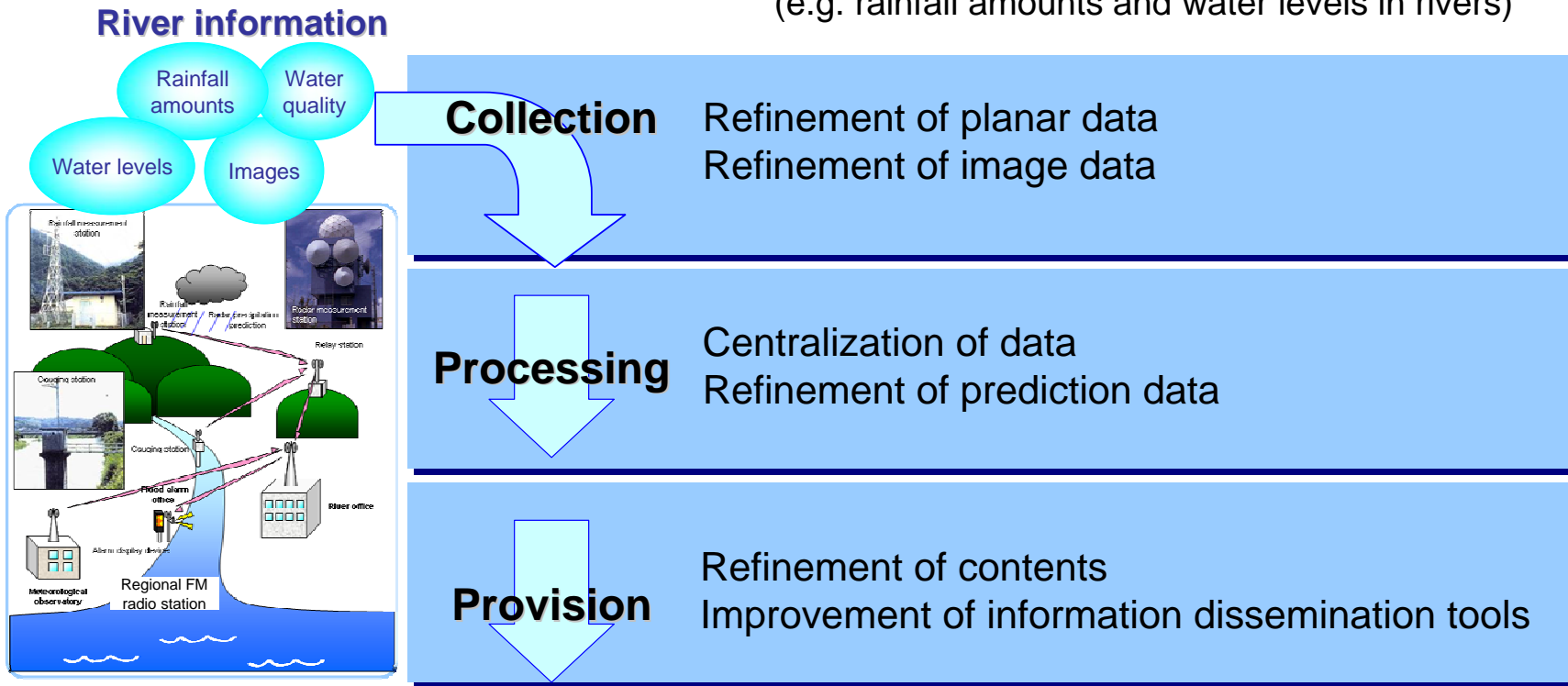
Contents

1. Objectives of river information management
2. Collection, processing and provision of real-time data
3. Provision of disaster information
4. Predicted rainfall
5. Run-off analysis and flood forecasting
6. Utilization of satellite-based rainfall information

1. Objectives of river information management

1-1 Objectives of river information management

Accurate, reliable and quick collection, processing and dissemination of river information
(e.g. rainfall amounts and water levels in rivers)



Increasing the efficiency of river-related work

Enhancing river administration services through information dissemination to the public

1-2 Adaptation measures to decreasing loss of life

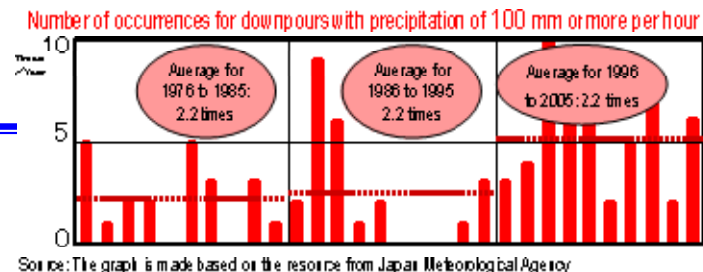
- Since it is difficult to totally protect everything from flood and other disasters, which are likely to be intensified by climate change, **adaptation strategies for climate change need to be developed aiming for “zero victims.”**
- Enhancing river information management is one of adaptive measures to decreasing loss of life.

Proposal of specific adaptation strategies

Climate Change Adaptation Strategies to Cope with Water-related Disasters due to Global Warming (Draft Policy Report)

- (1) Adaptation strategies using structures
- (2) Adaptation strategies in step with local community development
- (3) **Adaptation strategies with emphasis on crisis management**
 - 1) Promotion of preparation for responding to large-scale disasters
 - 2) Promoting non-structural measures based on new scenarios
 - 3) **Enhancement of forecasting and warning systems for floods, sediment-disasters and flood fighting**
- (4) Adaptation strategies to avoid drought risk
- (5) Adaptation strategies to river environment changes
- (6) Enhancement of observational systems for the impacts of climate change

To conduct such activities as flood fighting, evacuation and emergency restoration in disaster management, it is very important to provide residents and relevant organizations with forecasts and warnings based on the prediction of the precursors, timings and scales of floods, debris flows and storm surges.



2. Collection, processing and provision of real-time data

2-1 Collection of real-time data

2-1-1. Collection of point data

(e.g. rainfall amounts, water levels and water quality)

- Rain observation by ground gauges
- Telemetry system



2-1-2. Collection of area data (rainfall amounts)

- Radar rain gauge



2-1-3. Collection of image data

- CCTV network
- Fiber optic network



2-1-1 Rain observation by ground gauges



Tipping-Bucket Rain Gauge



Observation sites

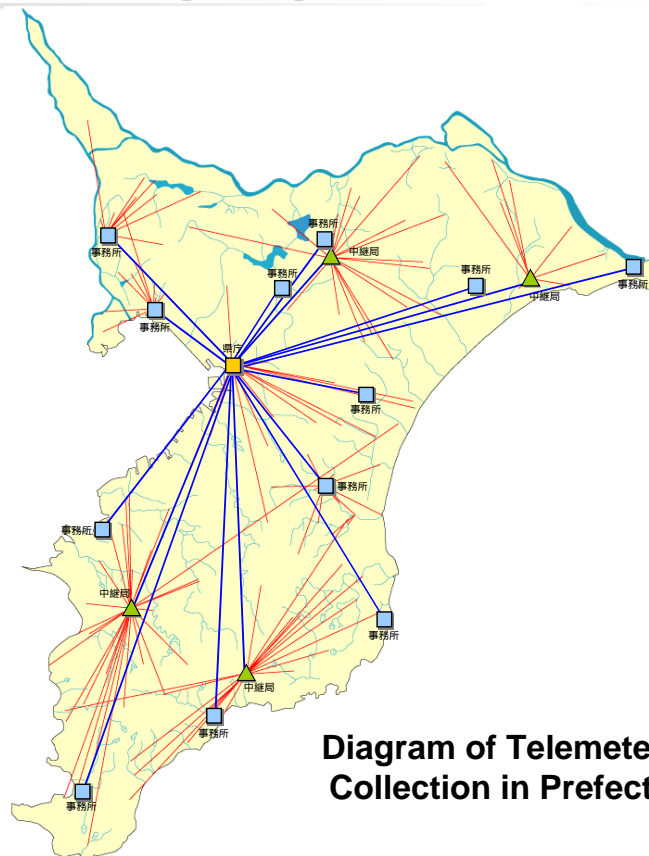


Diagram of Telemeter Data Collection in Prefecture A

The data obtained by telemeters are consolidated in one site, such as a regional bureau and a prefectural office, through the linking station. Then, they are sent to each office to update the real-time flood prediction calculations.

2-1-1 Telemetry system

Number of telemetry stations^{*1}

	River Bureau	Municipality	Road Bureau	Japan Meteorological Agency	Maritime Safety Agency	Geographical Survey Institute	Japan Water Agency	Other organization	Total
Rainfall amount	2238	4088	1010	1326	0	0	100	115	8877
Mean rainfall amount in the basin	818	295	0	0	0	0	6	84	1203
Snow cover	128	30	1	16	0	0	10	2	187
Water level	1886	3654	0	0	0	0	74	18	5632
Water intake	25	39	0	0	0	0	5	2	71
Water quality	310	26	0	0	0	0	58	1	395
Dam	120	185	0	0	0	0	27	150	482
Weir	61	12	0	0	0	0	15	2	90
Pump station	252	69	0	0	0	0	3	1	325
Weather	33	0	0	0	0	0	7	0	40
Oceanographic conditions	29	53	0	66	29	25	3	0	205
Groundwater level	16	0	0	0	0	0	0	0	16
Total	5916	8451	1011	1408	29	25	308	375	17523

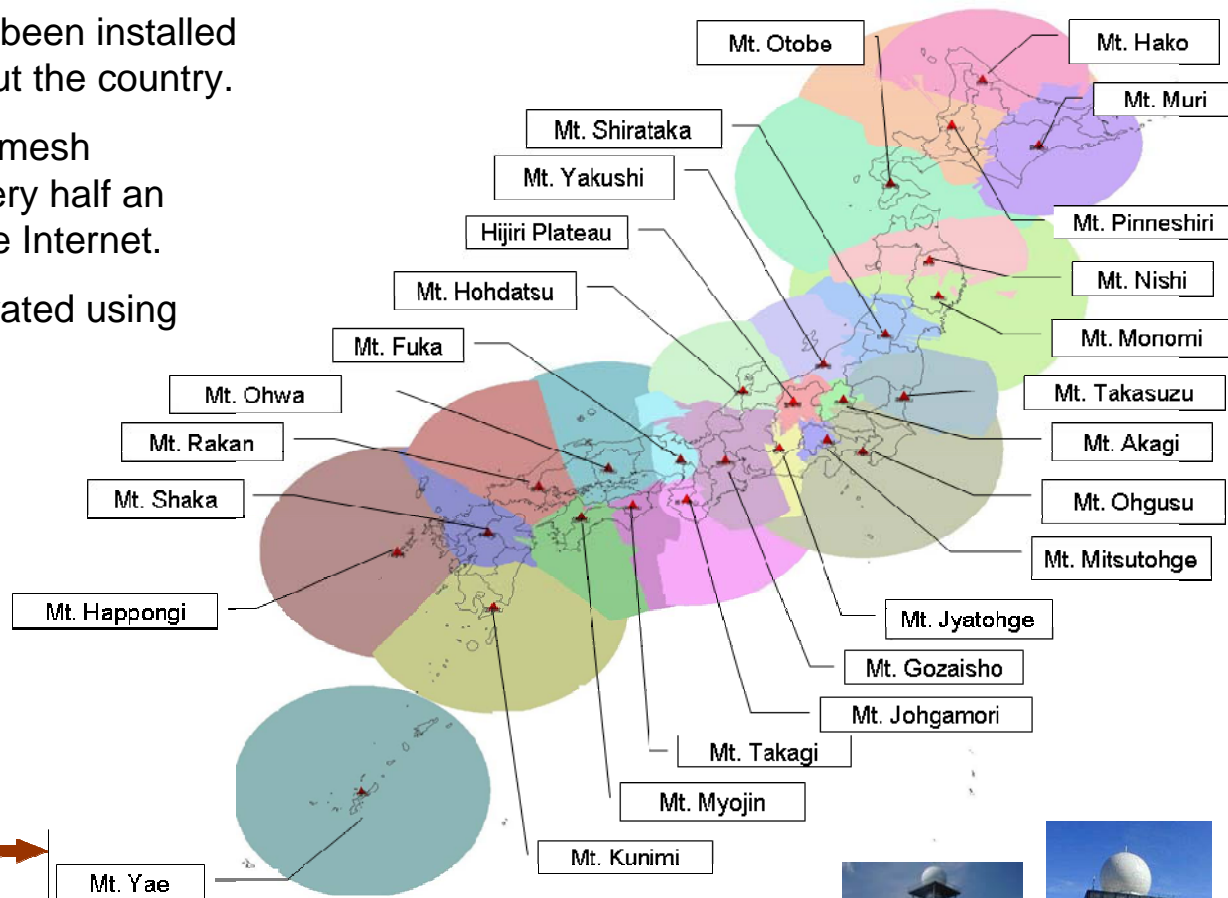
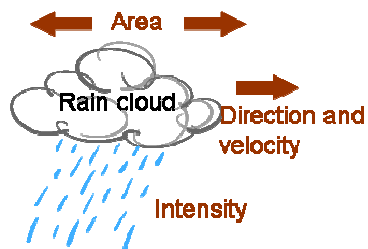
*1 Stations using a uniform river information system (as of March 2007)

2-1-2 Locations of radar rain gauges

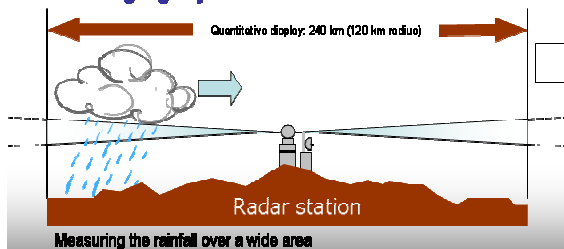
Radar rain gauges have been installed at 26 locations throughout the country.

The information of 1-km mesh resolution is updated every half an hour and available on the Internet.

The radar data are calibrated using the ground data.



Radar rain gauge system



2-1-3 CCTV network

Ministry of Land, Infrastructure and Transport, Regional Development Bureaus and River Offices have real-time access to 3,900 CCTV images available on IP (Internet protocol) network.



CCTV images are used for developing disaster control plans.



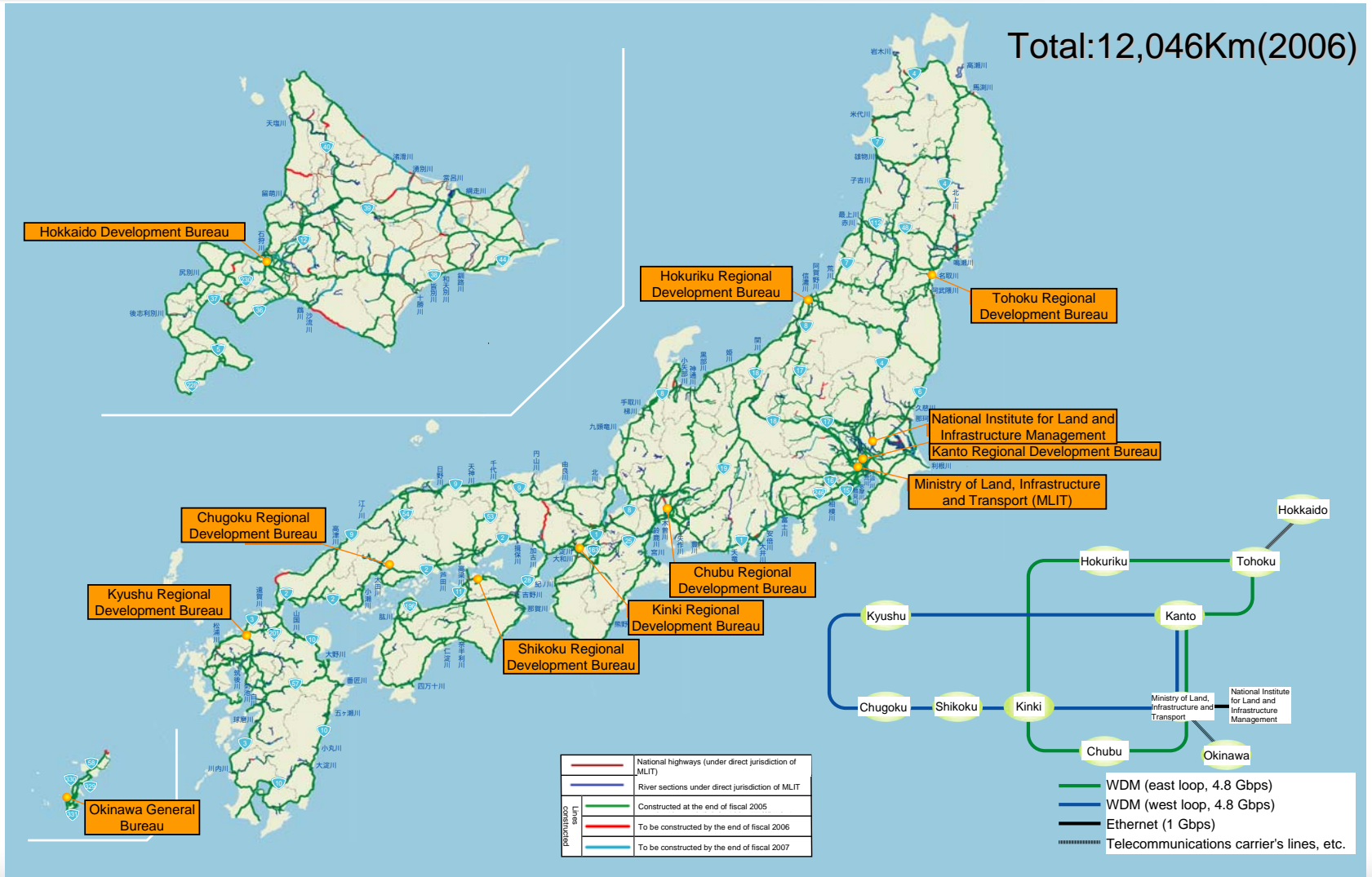
**Sample image
(Yodo River in Osaka on August 14, 2007)**

Number of CCTV sets installed

	Estimate at the end of March, 2007				
	Road	River	Sediment control	Other	Total
Hokkaido	1,095	725	55	17	1,892
Tohoku	841	610	36	64	1,551
Kanto	1,153	1,210	58	91	2,512
Hokuriku	521	525	147	66	1,259
Chubu	999	662	101	27	1,789
Kinki	697	766	55	46	1,564
Chugoku	711	685	-	99	1,495
Shikoku	657	299	30	40	1,026
Kyushu	742	1,070	84	52	1,948
Okinawa	50	46	-	-	96
Total	7,466	6,598	566	502	15,132

Source: Data collected by Electricity and Telecommunication Office in October 2006

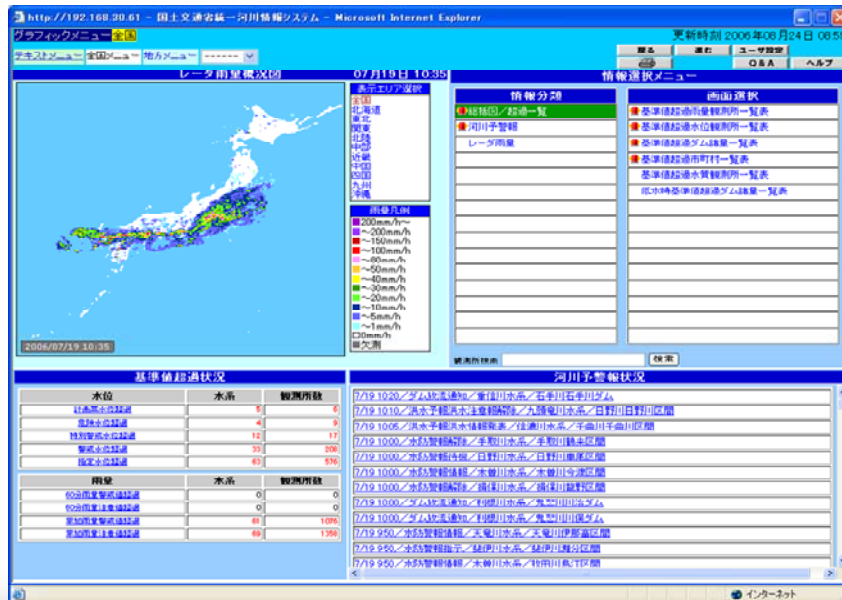
2-1-4 Fiber optics network



River Bureau and Road Bureau have jointly laid fiber optics network lines.

2-2 Uniform river information system

- Foundation of river and basin integrated communications (FRICS) developed an integrated river information system.
- The uniform river information system aims at sharing and standardizing river administration data including river water levels and rainfall amounts.
- River information systems developed by individual regional development bureaus have been integrated into a national river information system. Regional development bureaus can customize the system according to their requirements.



2-3-1 River disaster prevention information

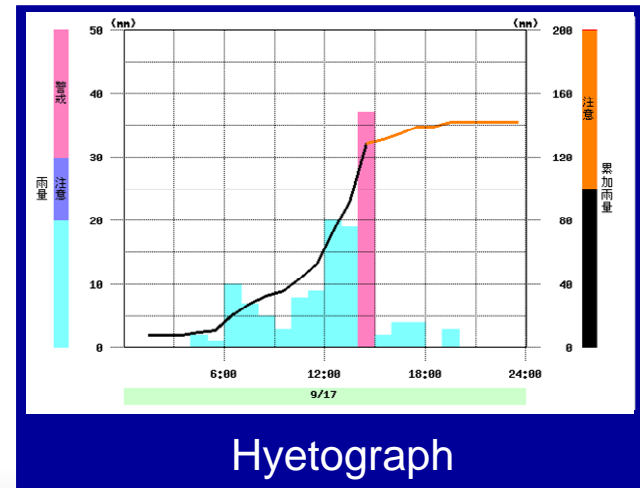
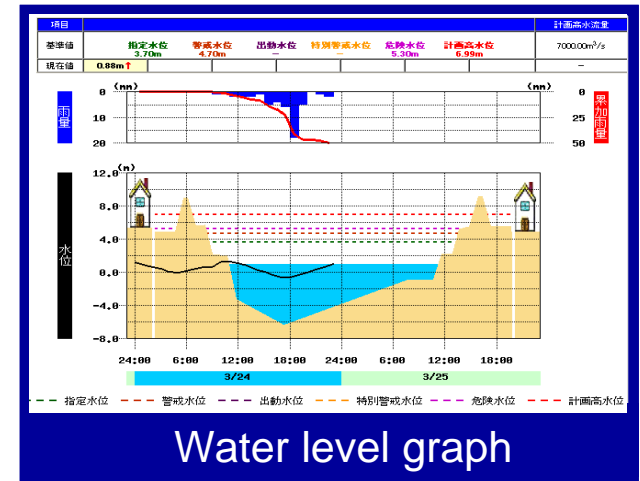
Information to be provided

- Radar rain gauge data
- Telemetry data (water levels, rainfall amounts, etc.)
- Flood forecasting and warning
- Dam-related parameters (notice of release of water from the reservoir, reservoir water storage, etc.)



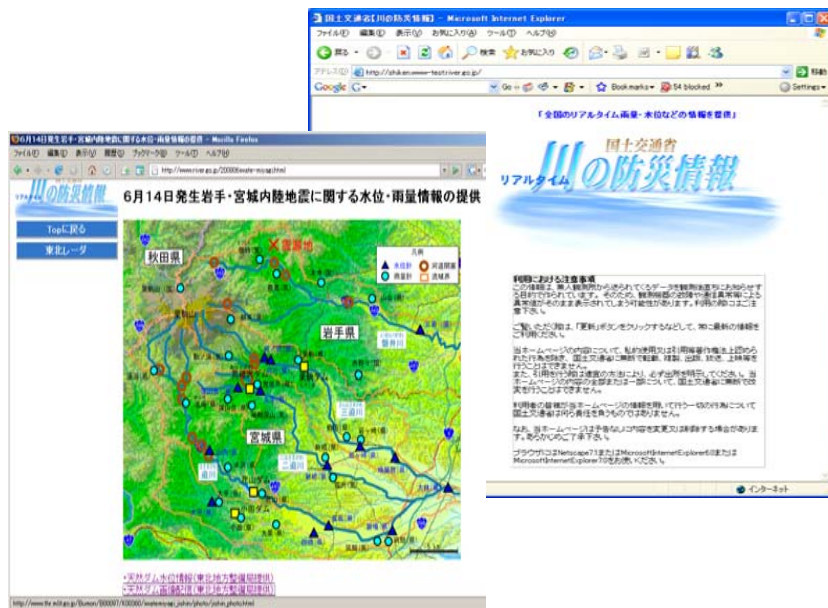
<http://www.river.go.jp/>

Portal of "river disaster prevention information" website



2-3-2 Data provision via the Internet and cellular phone

- River disaster prevention data such as water levels, rainfall amounts and dam-related parameters have been disseminated since fiscal 2001 via the Internet and cellular phone.
- Numerous improvements have been made since fiscal 2007 such as additional provision of data of prefectural governments and applicability to all cellular phone service companies.



The Internet since April 2001.



Cellular phone (since April 2001)

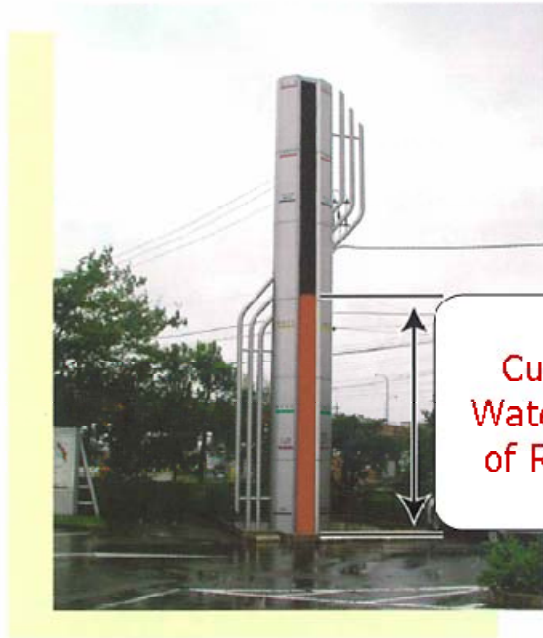
*Applicable to multiple carriers including au and Softbank since April 2007.

3. Provision of disaster information

3-2 Water-level display tower, etc.

The water-level display tower to indicate the current WL of River B with red lights.

Water Level Observation Point A



Current
Water level
of River B

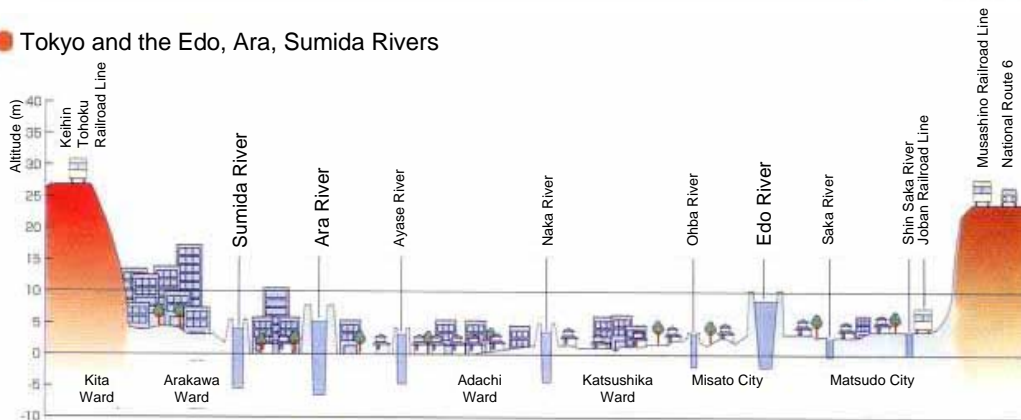


Normal WL

WL during
floods



● Tokyo and the Edo, Ara, Sumida Rivers



Flood water depth (projected)
Sign in town

the auspices of UNESCO



3-3 Awareness program

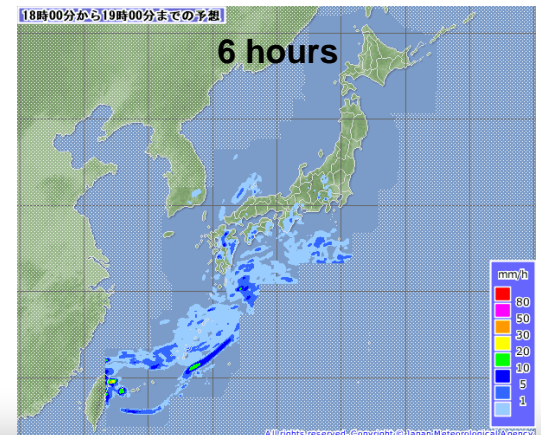
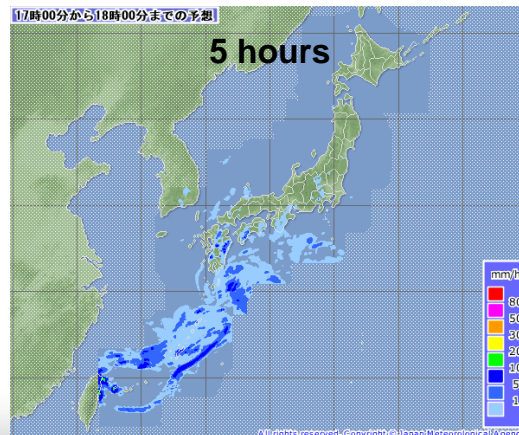
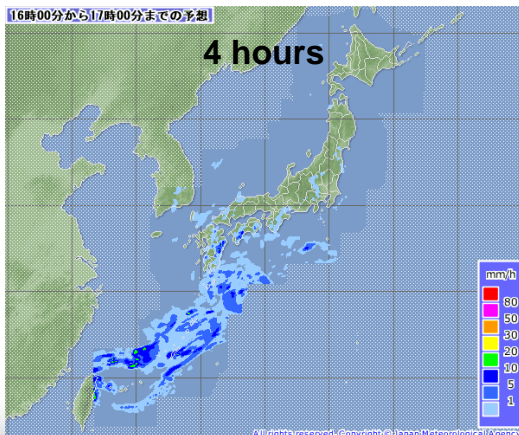
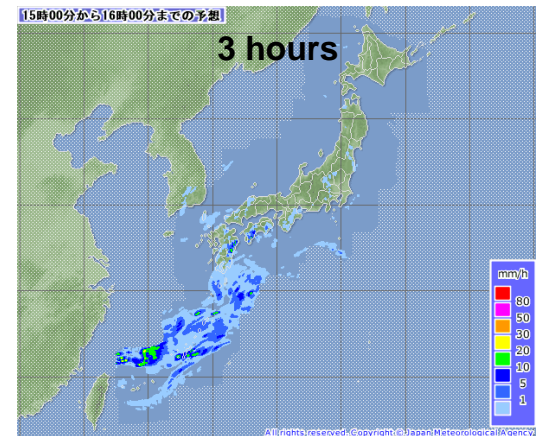
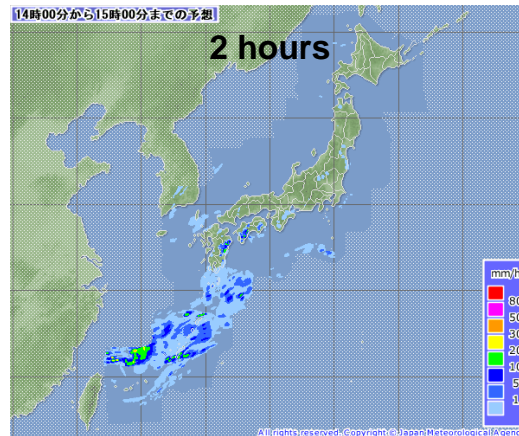
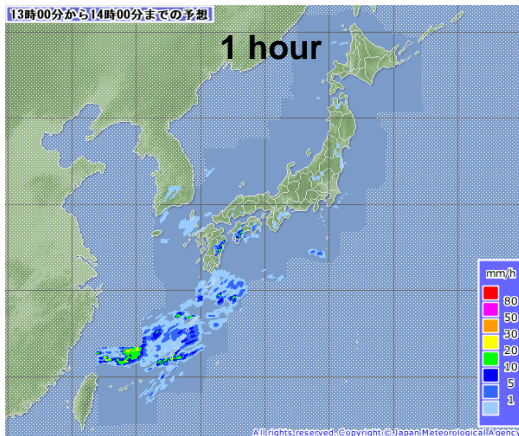
- To enhance a flood awareness of residents
- River information (under normal condition)
Residents understand a flood risk, and how to act and where to evacuate in flood.
- River information (under abnormal condition)
Residents can make an accurate judgment to start evacuation.



4. Predicted rainfall

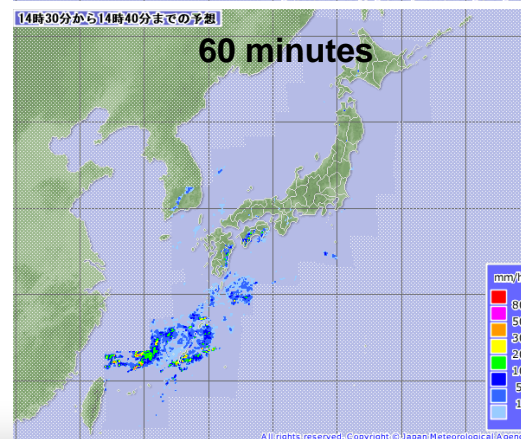
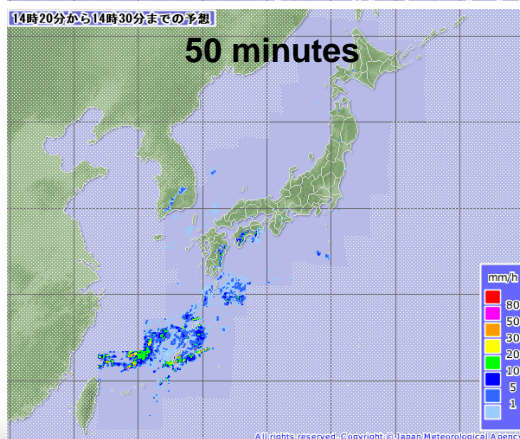
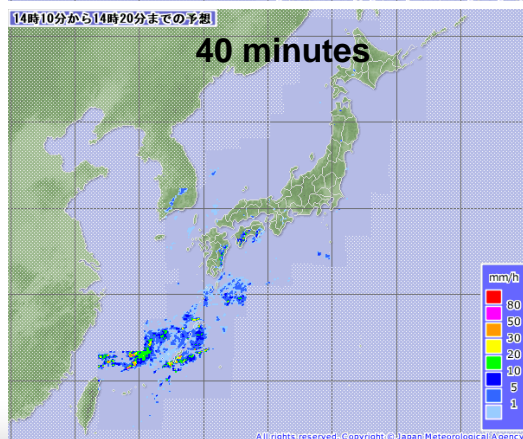
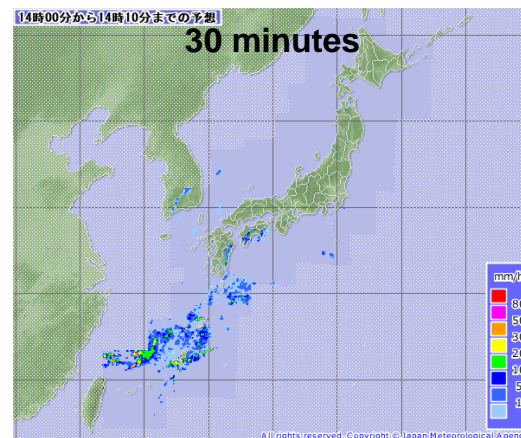
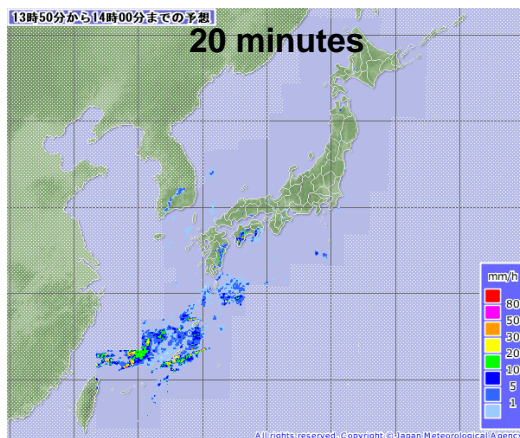
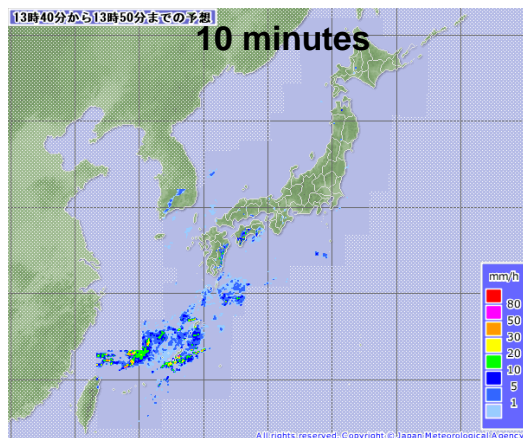
4-1 Short-period rain prediction

Short-Period Rain Prediction is issued every 30 minutes to provide forecasts of one-hour precipitation for the next 6 hours with 1-km spatial resolution. Not only changes in rain distribution, but also geographical factors and numeric estimates are taken into considerations.



4-2 Precipitation nowcast

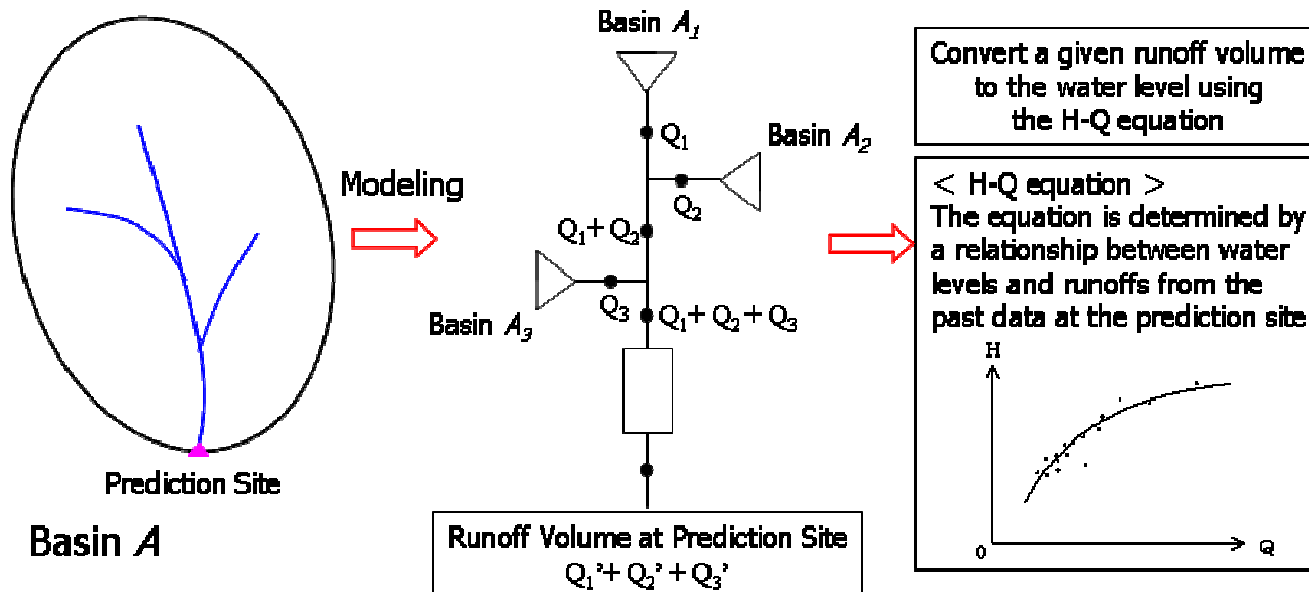
Precipitation Nowcast provides **10-minute precipitation forecasts with 1-km spatial resolution up to one hour ahead**. Since it gives priority to quick forecasting, the precision is not as high as the Short-Period Rain Prediction. However, it is very useful for swift disaster-prevention activities.



5. Run-off analysis and flood forecasting

5-1-1 Flood prediction by storage function model

- Most commonly used in Japan.
- It predicts a runoff volume of the prediction site by a runoff model using the storage function method and a water level by means of the H-Q equation.



< Storage function of the river basin >

$$S(t) = kq(t)^p$$

$$\frac{dS(t)}{dt} = r(t - t_l) - q(t)$$

$S(t)$: apparent storage height of basin (mm)
 $q(t)$: runoff over time t
 r : average rainfall of basin
 t_l : lag time, k
 p : constant

< convert the flow volume from the runoff >

$$Q(t) = \frac{A}{3.6} fq(t) + Q_B$$

A : basin area (km²)
 f : Runoff ratio
 Q_B : base flow (m³/s)

< Storage function of the river channel >

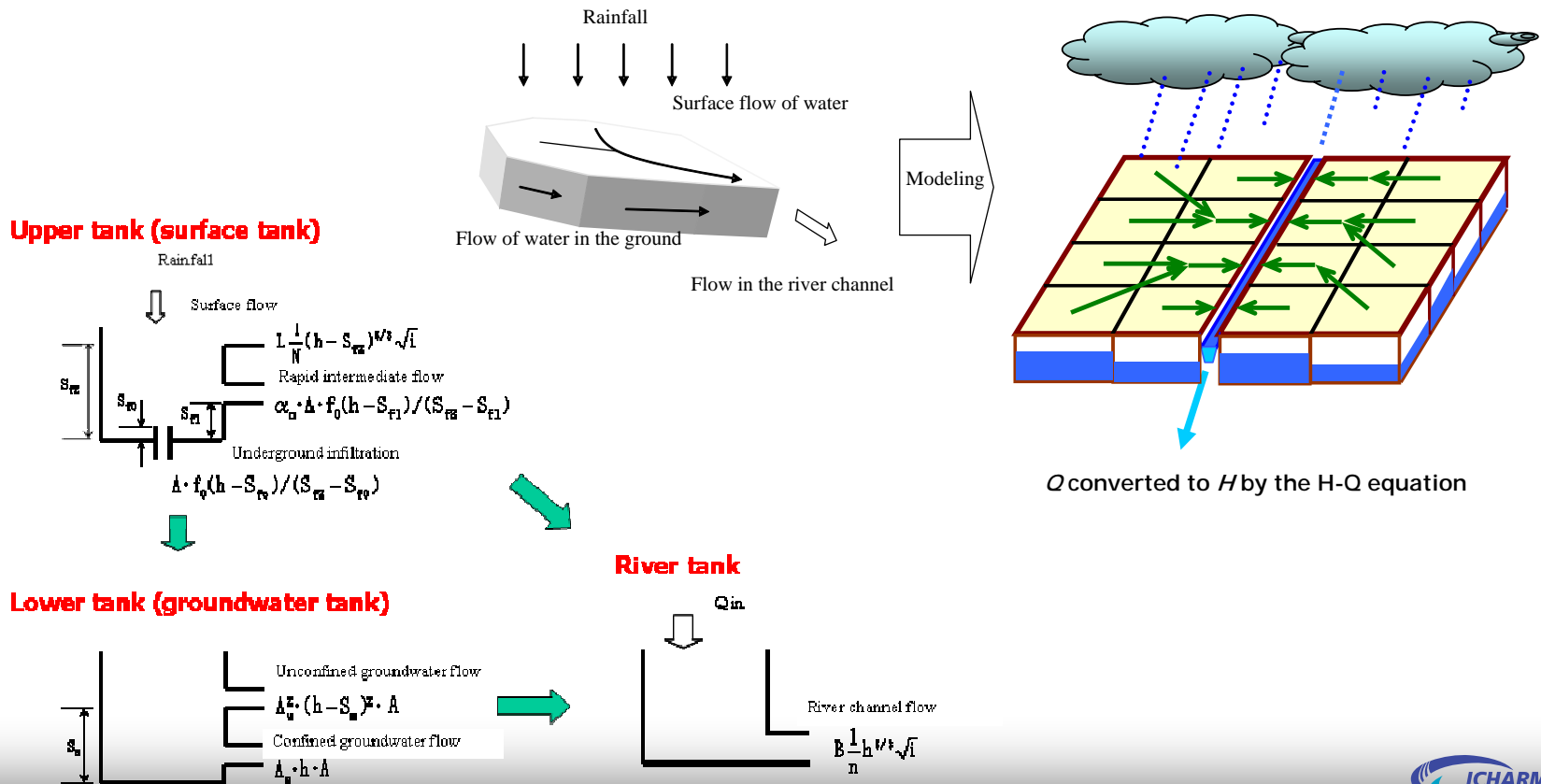
$$S(t) = KQ_u(t)^P - T_L Q_o(t)$$

$$\frac{dS(t)}{dt} = Q_i(t - T_{Lc}) - Q_o(t)$$

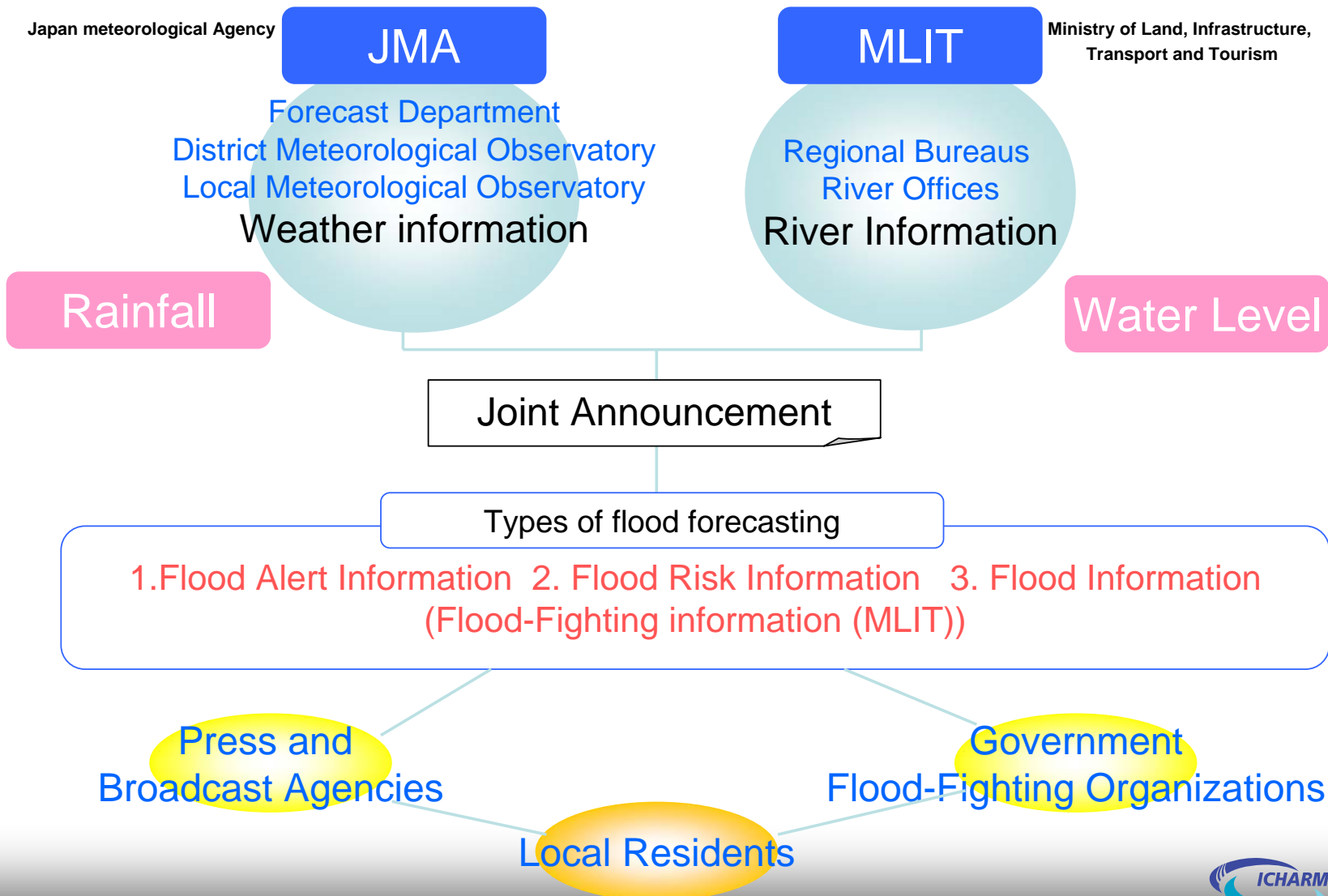
S : storage function of river channel (m³)
 Q_o : river channel downstream boundary outflow (m³/s)
 Q_i : river channel upstream boundary inflow
 K, P, T_L, T_{Lc} : constants

5-1-2 Flood prediction by distributed model

- It is a physical model which segments a basin into meshes and calculates a runoff volume assuming that rain falls on each mesh.
- With this method, rain distribution is modeled more precisely in comparison with the Storage Function Model.

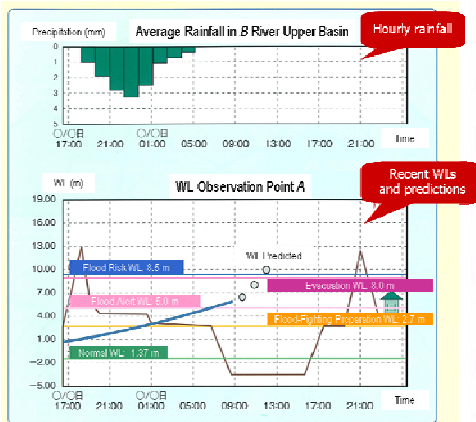


5-2-1 Flood forecasts jointly announced by MLIT and JMA

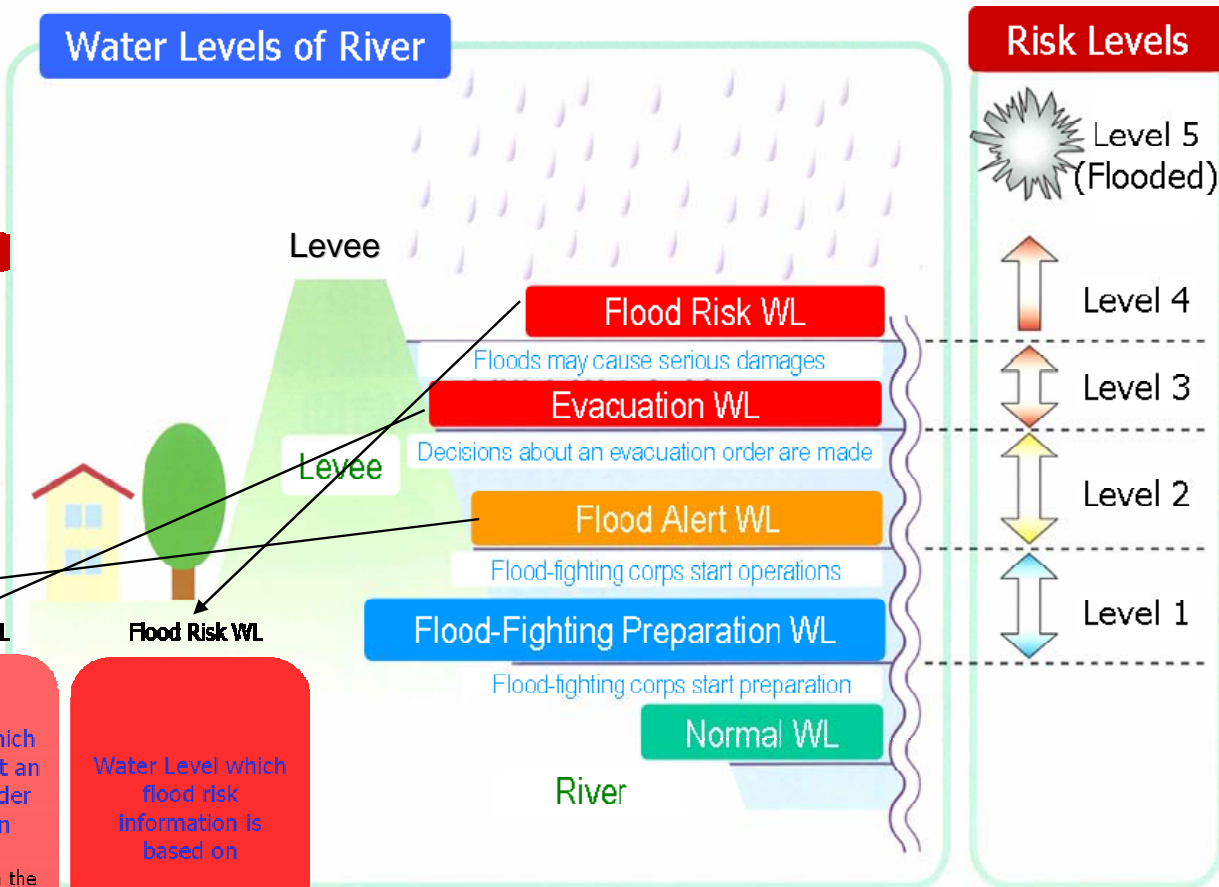


5-2-2 Water levels used to issue flood forecasts

Example of Flood Forecasts



Water Levels of River



Flood Alert WL

Water level which flood alert information is based on

When the water level exceeds this level, slope collapse, erosion and leaks may occur. Flood-fighting organizations start operations and stay on alert for rivers.

Evacuation WL

Water level which decisions about an evacuation order are based on

Water level which the local government refers to upon making decisions about evacuations, etc.

Flood Risk WL

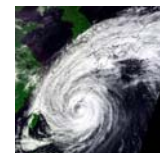
Water Level which flood risk information is based on

Water Level at which floods may cause a serious disaster.

5-2-3 Flood forecasts

Flood Forecasts by JMA

Announced by the local meteorological observatory of JMA in its area of administration. Medium- to small-size rivers other than those designated for flood forecasts



Weather advisories	Announced when disasters may occur by heavy rain, gale, high tide, etc.
Weather warnings	Announced to warn of a risk of serious disasters by heavy rain, gale, high tide, etc.
Flood advisories	Announced when floods may cause damages
Flood warnings	Announced to warn of a risk of floods

Warnings for Flood Fighting issued by MLIT

Issued with the purpose for MLIT or the prefectural government to provide flood-fighting organizations with a guideline for their activities.



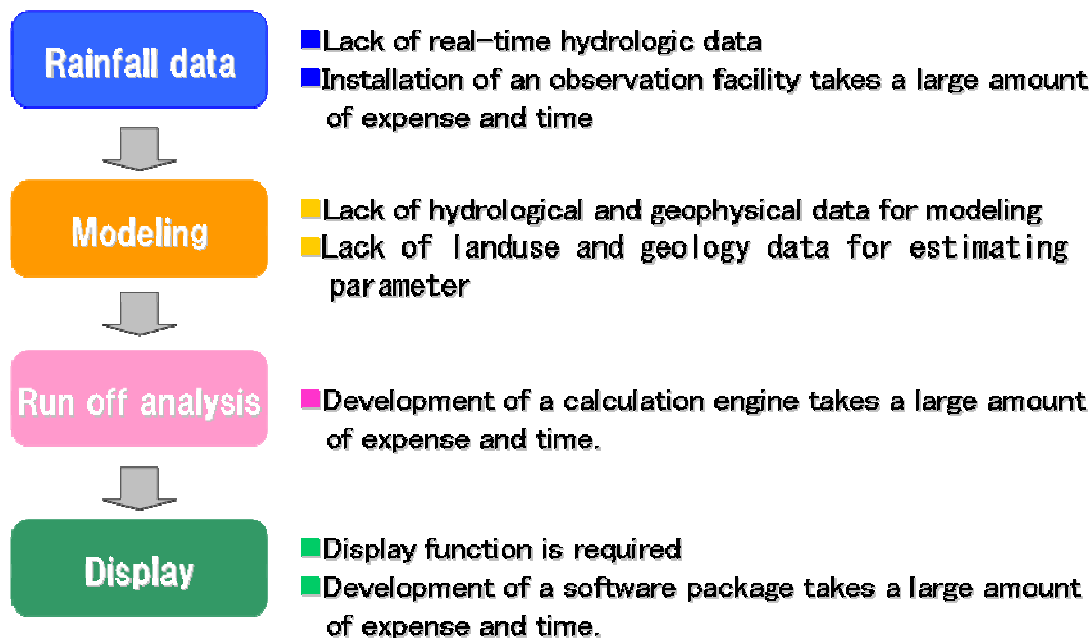
Standby	Alerts that flood-fighting organizations need to be ready for operation in case floods may occur or WL is predicted to increase.
Preparation	Warns that flood-fighting organizations need to be prepared for operation, at the same time, sending information about flood control, providing flood control equipments and materials, securing communication and transportation means.
Mobilization	Warns that flood-fighting organizations need to be mobilized when WL is predicted to exceed the Flood Alert WL.

6. Utilization of satellite-based rainfall information

Adaptation measurement in developing country

6-1 Necessity of satellite-based rainfall data

- In the countries where river improvements are not sufficient, smooth evacuation from flooding is important for decreasing loss of life and properties.
- Dissemination of risk by hazard maps, etc. and direction of evacuation by issuing flood forecasts and alerts are necessary.
- However, in reality, development of a flood warning system in these countries has not advanced properly because of financial difficulty, lack of rainfall data, etc.



Non real time observation



No data of river discharge

Technical issues for flood forecasting

6-2-1 Features of satellite-based rainfall data (3B42RT)

● Current System

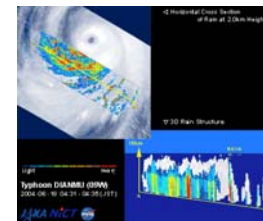
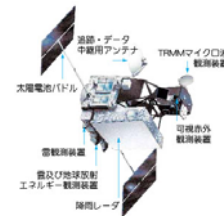
Launch of Tropical Rainfall Measuring Mission (TRMM) satellite in 1997
Near real time data “3B42RT” since 2002 from TRMM, orbital satellites and geostationary satellites

● Features

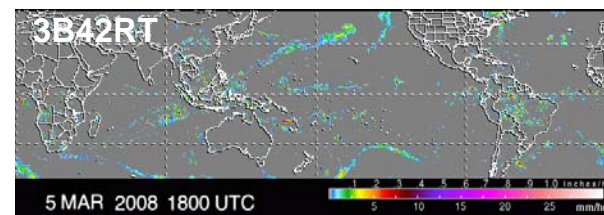
3-dimensional analysis of rainfall structure
Global coverage including oceans

● 3B42RT:NASA

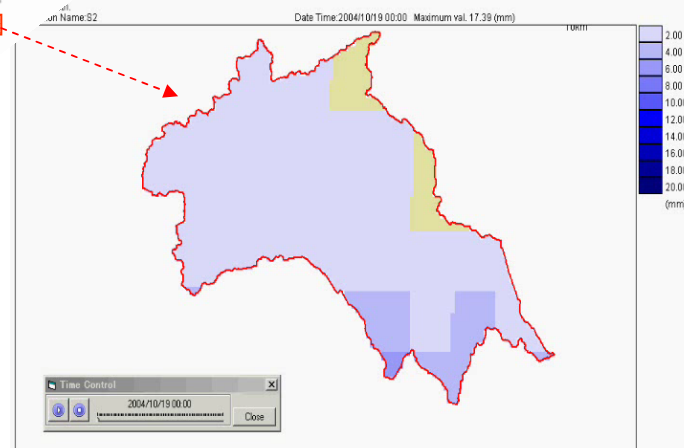
Mesh Size: 0.25 degrees of latitude and longitude
(rectangle of about 30km by 20km on 40N)
Coverage Area: between 60N and 60S latitude
Data Delivery: every 3 hours (not hourly)
Near-real-time basis with several hours time lag
<ftp://trmmopen.gsfc.nasa.gov/pub/merged/mergeIRMicro/>



JAXA HP



NASA HP

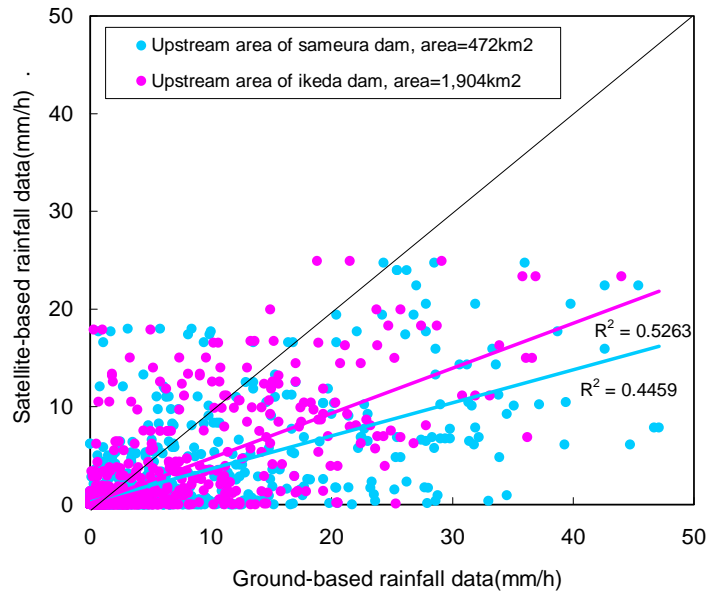
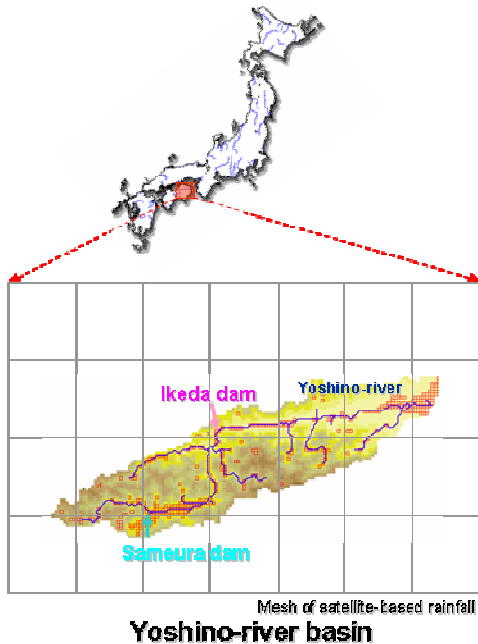


Satellite-based rainfall in Tone river in Japan

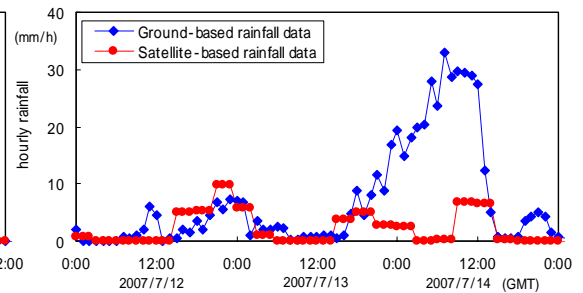
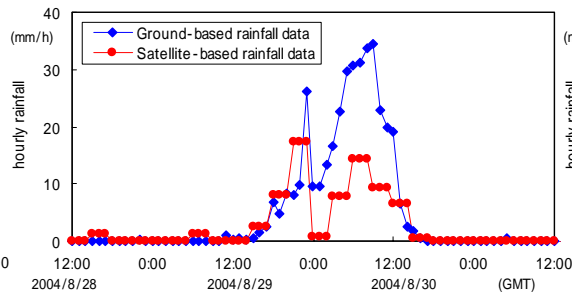
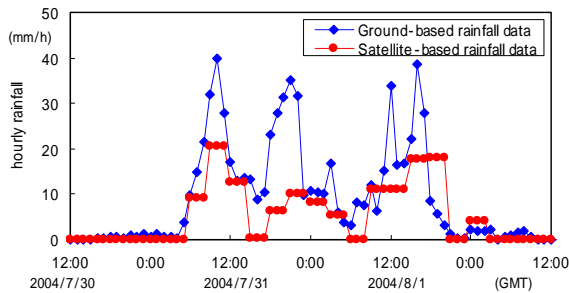
Product of satellite-based rainfall data

Product name	3B42RT	CMORPH				QMORPH	
Builder	NASA/GSFC	NOAA/CPC				NOAA/CPC	
Coverage	60N ~ 60S	60N ~ 60S				60N ~ 60S	
Spatial resolution	0.25°	8km	0.25°	0.25°	0.5°	8km	0.25°
Time resolution	3hours	30minutes	3hours	1day	3hours	30minutes	30minutes
Delay of delivery	10hours	15hours				2.5hours	
Timing of data updating	Every 3hours (UTC)	Every 30minutes (UTC)	Every 3hours (UTC)	Every 1day (UTC)	Every 3hours (UTC)	Every 30minutes (UTC)	Every 30minutes (UTC)
Coordinate system	WGS						
Data archive	Dec. 1997 ~	Recent 4days	Dec. 2002 ~	Jan. 2004 ~	Dec. 2002 ~	Recent 2days	
Data source	TRMM-TMI DMSP-SSM/I Aqua-AMSR-E, AMSU-B IR	TRMM-TMI DMSP-SSM/I Aqua-AMSU-B IR					

6-2-2 Accuracy of satellite-based rainfall data



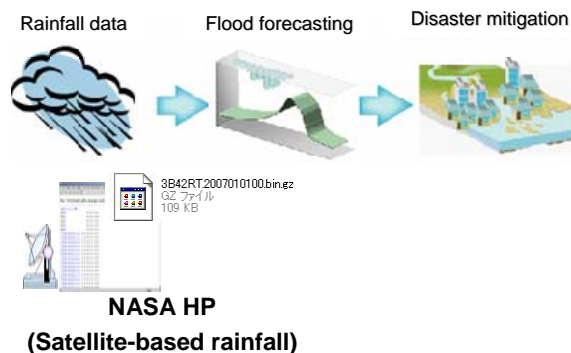
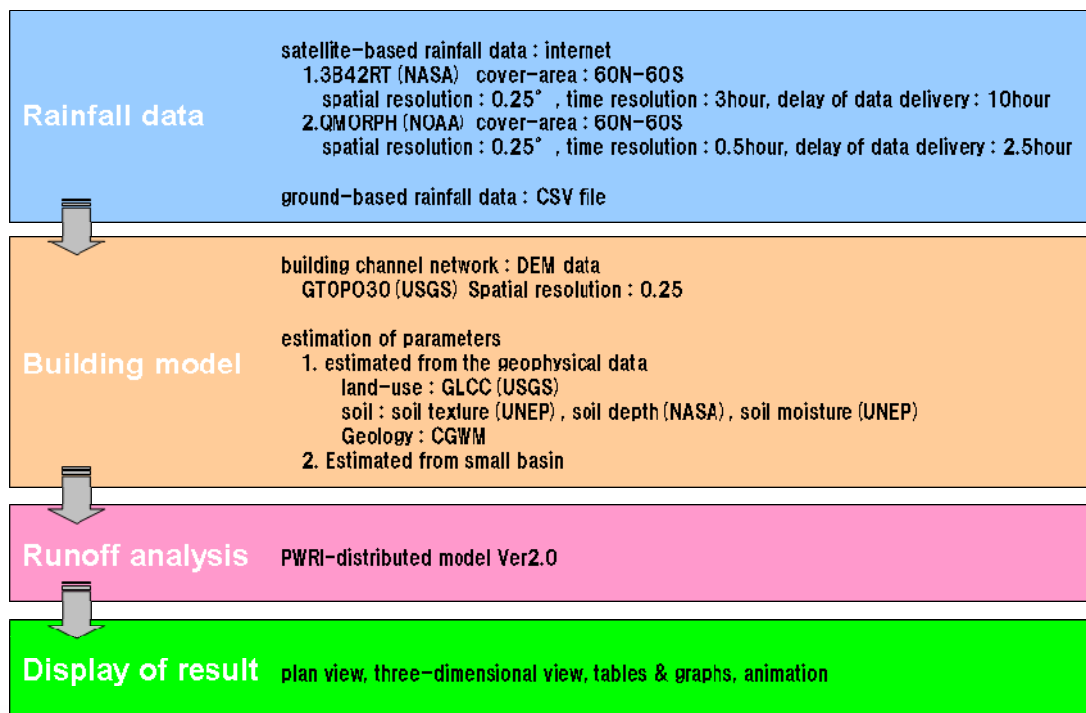
**Comparison with satellite-based and ground-based rainfall
(major ten flood in 2002-2007)**



Comparison with satellite-based and ground-based rainfall of Sameura dam basin

6-3 Flood forecasting system for developing country

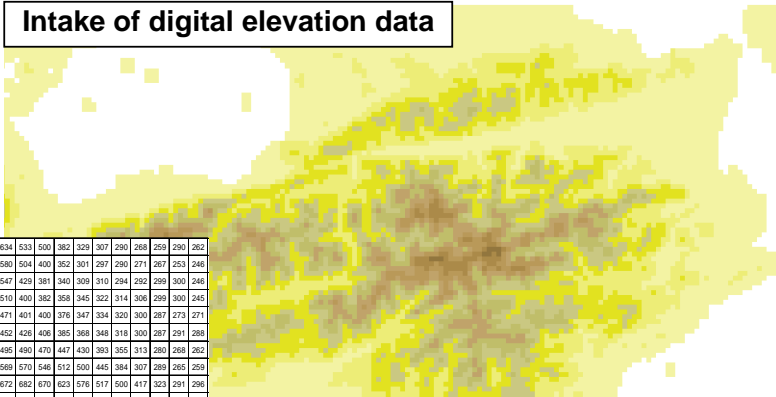
- Our team is developing a concise flood-runoff analysis software as a toolkit.
- This system implements interfaces to input not only ground-based but satellite-based rainfall data, GIS functions to construct flood-runoff models, a default runoff analysis model, and interfaces to display output results.



Integrated Flood Analysis System

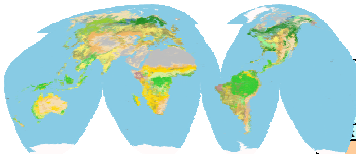
6-4 Modeling function

Intake of digital elevation data



800	634	533	500	382	329	307	290	288	259	290	262
688	580	504	400	352	301	297	290	271	267	253	248
688	547	429	381	340	309	310	294	292	299	300	248
643	510	400	382	358	345	322	314	306	299	300	245
600	471	401	400	376	347	334	320	300	287	273	271
491	452	428	408	385	368	348	318	300	287	291	288
504	496	490	470	447	430	393	355	313	280	268	262
560	569	570	546	512	500	445	384	307	289	265	259
653	672	682	670	623	576	517	500	417	323	291	296
800	806	828	827	731	668	586	587	548	382	297	288

IFAS creates a basin boundary and a river channel network use of digital elevation data.

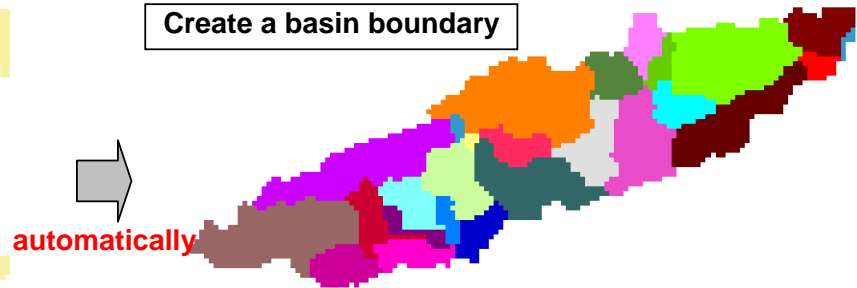


Landuse data
GLCC (USGS HP)

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	Grassland
Cropland/Grassland Mosaic	
Cropland/Woodland Mosaic	
Grassland	
Shrubland	Forest
Mixed Shrubland/Grassland	
Savanna	
Deciduous Broadleaf Forest	
Deciduous Needleleaf Forest	Water Bodies
Evergreen Broadleaf Forest	
Evergreen Needleleaf Forest	
Mixed Forest	
Water Bodies	Wetland
Herbaceous Wetland	
Wooded Wetland	
Barren or Sparsely Vegetated	Grassland
Herbaceous Tundra	
Wooded Tundra	
Mixed Tundra	
Bare Ground Tundra	
Snow or Ice	Water Bodies

IFAS estimates parameter based on the classification that we set up beforehand.

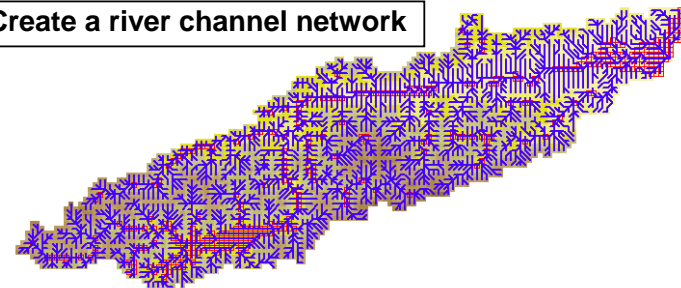
Create a basin boundary



automatically

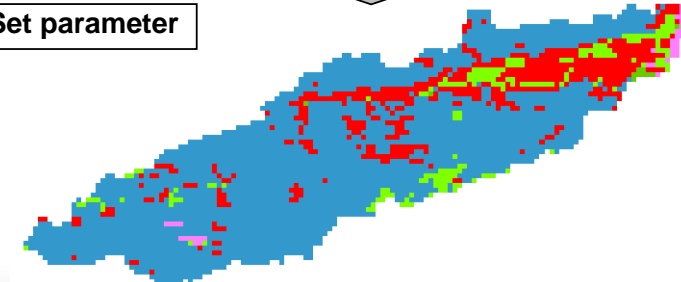
automatically

Create a river channel network

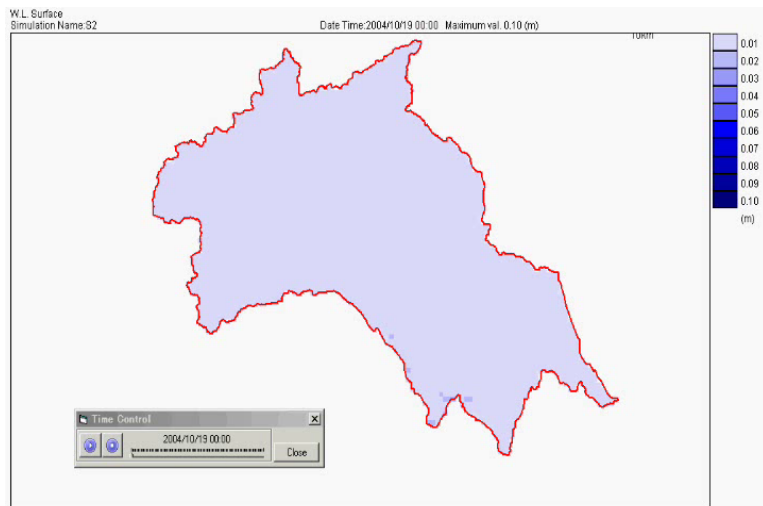
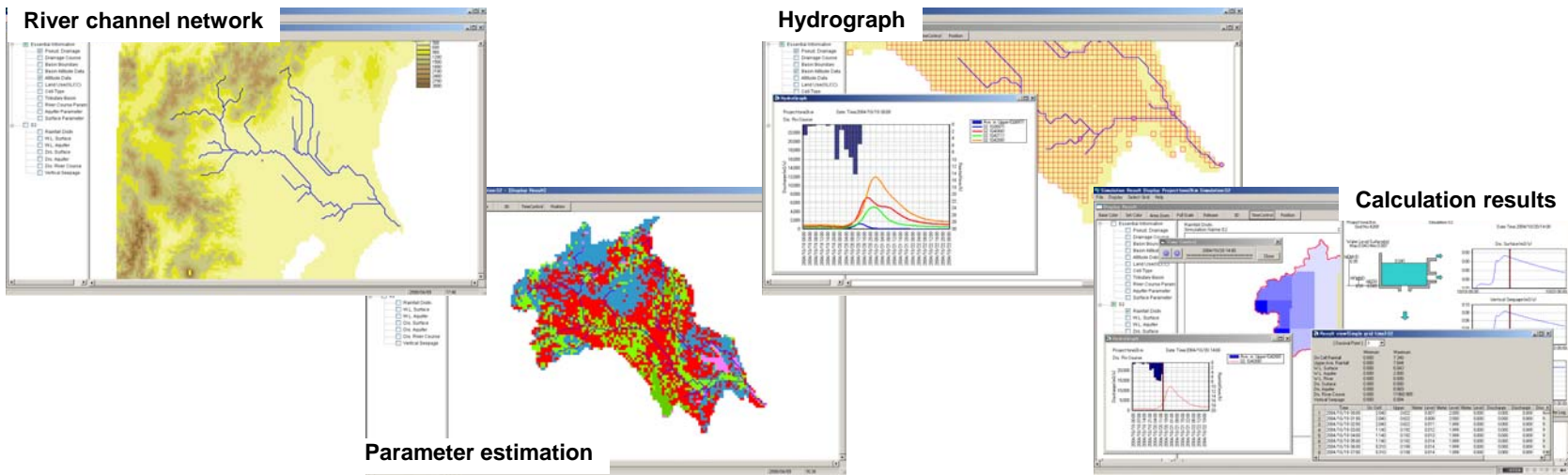


automatically

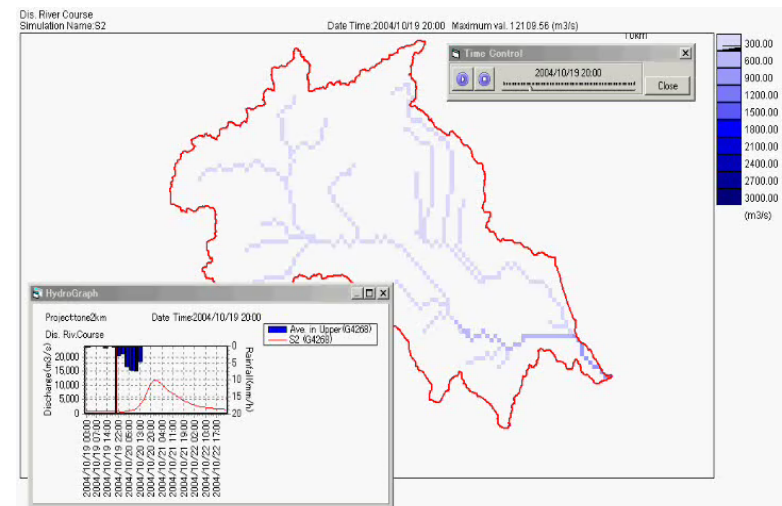
Set parameter



6-5 Example display of our flood forecasting system



Water level of a upper tank



River discharge

6-6 On going works

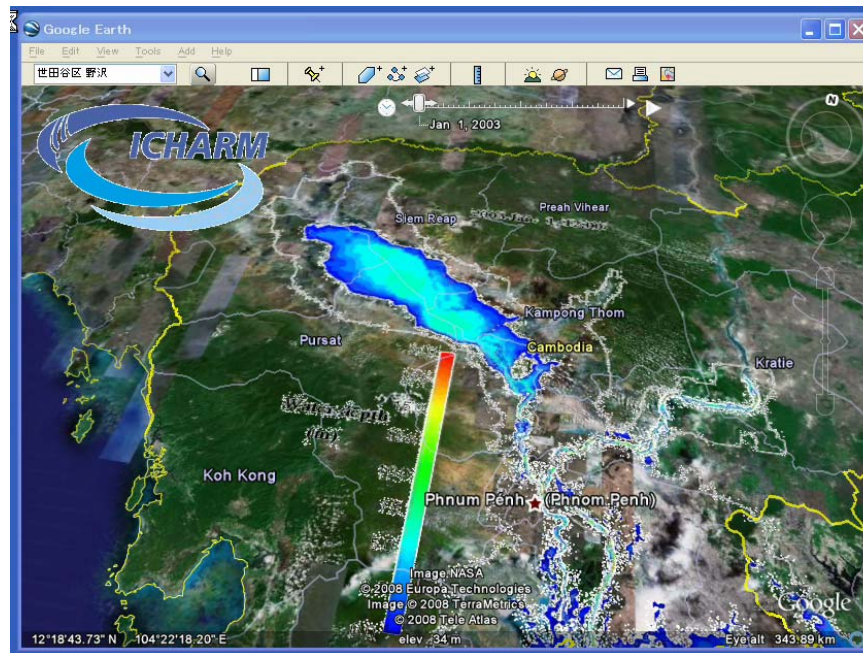
Improvement accuracy and resolution of results:

to calibrate a set up parameter with some large basins

to implement functions united at the distribution time delay and updating time of satellite-based rainfall
(correcting function of satellite-based rainfall using ground based rainfall)

Display an inundation depth:

to implement a linkage function with an inundation model



Tonle Sap Lake Flood in 2003

- We hope this system is useful for immediate and efficient implementation of flood forecasting and warning system in developing countries.