Global Flood Alert System (GFAS)

Kazuo UMEDA
International Flood Network (IFNet) Secretariat
Director of 2nd Research Department
Infrastructure Development Institute-Japan (IDI)
New Kojimachi Bldg. 5-3-23 Kojimachi, Chiyoda-ku, Tokyo 102-0083, Japan

Abstract: Global Flood Alert System (GFAS) is an attempt to make the best use of satellite rainfall data in flood forecasting. The project of GFAS is promoted both by Ministry of Land, Infrastructure and Transport-Japan (MLIT) and Japan Aerospace Exploration Agency (JAXA), under which Infrastructure Development Institute-Japan (IDI) has been working on the development of Internet-based information system and just launched trial run of GFAS in April 2006 on International Flood Network (IFNet) website. The function of GFAS is to connect space agencies and hydrological services/river authorities in charge of flood forecasting and warning by providing global rainfall information in maps, text data e-mails and so on which is produced from binary global rainfall data downloaded from National Aeronautics and Space Administration (NASA) website. Although the effectiveness of satellite rainfall data in flood forecasting and warning has yet to be verified, satellite rainfall is expected to play an important role to strengthen existing flood forecasting systems by diversifying hydrological data source.
Keywords: satellite rainfall data, flood forecasting.

1. Flood Disasters

1.1 World Trend

In recent years it seems that the mass media have been carrying more reports of major flood disasters year after year, the most notably flooding of the Elbe river in central Europe and Mozambique in Southeast Africa in 2002, the Rhine river in 2003 and Hurricane Katrina in the USA in 2005.

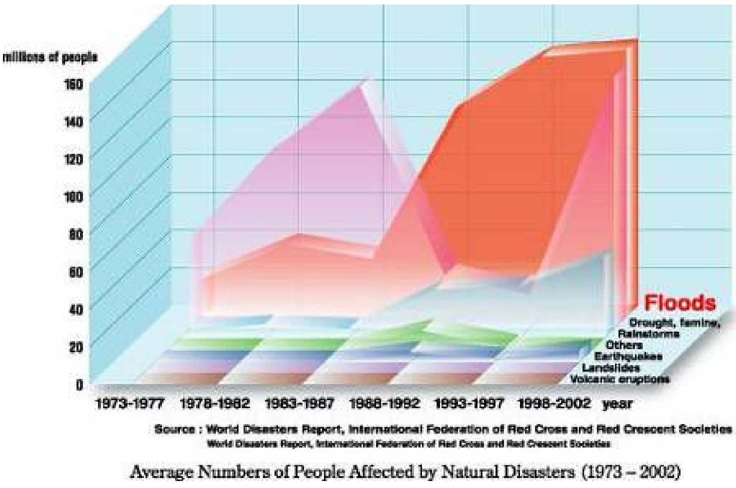
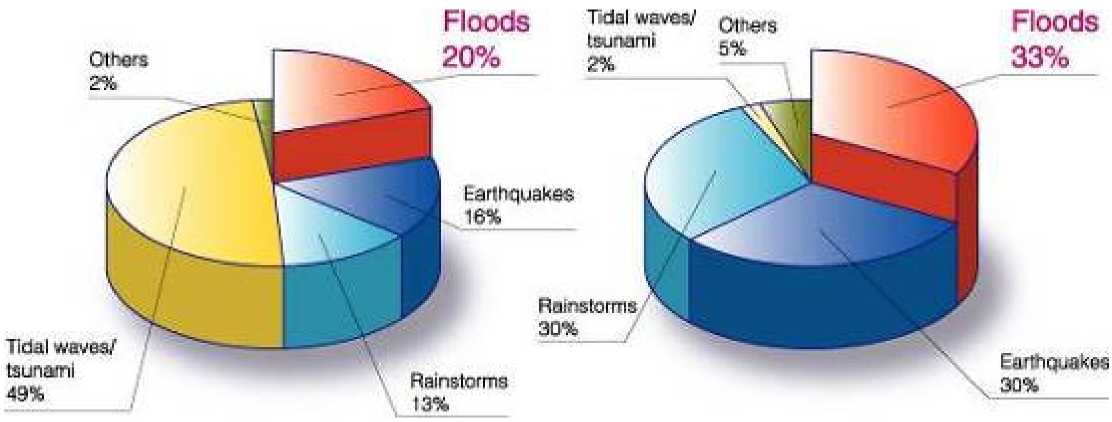


Figure 1 Average number of people affected by natural disasters (1973 – 2002)

Source: "World Disaster Report", International Federation of the Red Cross and Red Crescent Societies (IFRC)

Figure 1 which was drawn by the statistics of World Disaster Report released by International Federation of the Red Cross and Red Crescent Societies[1)], shows the number of persons affected by natural disasters from 1973 to 2002. The red line represents Floods and pink shows Drought/Famine, while other natural disasters shown are, in order from back to front, Rainstorms, Others, Earthquakes, Landslides and Volcanic Eruptions. Up until the mid-1980s, droughts accounted for the bulk of damage associated with natural disasters. The proportion dropped slightly after the late 1980s but has recently started rising again. Meanwhile, damage due to flooding has risen sharply since the late 1980s, and flooding now accounts for a significant proportion of all natural disasters in terms of the number of people affected. In 2002 alone, flood disasters impacted on over 140 million people. Unfortunately this statistics is made every five years and doesn't include Indian Ocean Earthquake and Tsunami in December 2004.

As the statistics of Indian Ocean Earthquake and Tsunami are available at the International Disasters Database "EM-DAT"[2)] of Center for Research on the Epidemiology of Disasters (CRED) at the University of Leuven in Belgium, another expression of disaster trend can be made as in Figure 2 which shows the human and economic losses associated with natural disasters during the latest decade 1995 – 2004. Tidal waves/tsunami account for roughly half of total death toll by natural disaster, and the vast majority of these are involved in the Indian Ocean Ttsunami. Floods are ranked second with 20% of total deaths, followed by earthquakes with 18%. In terms of economic losses Floods account for the largest portion at 33%. It should also be noted that floods occur almost every year and can repeatedly hit the same rivers/areas, since they are caused by annual pattern of climatic phenomena such as seasonal rainfall, typhoons, hurricanes and cyclones.



Deaths: 470,000

Economic loss: US$49 billion

Figure 2 Human and Economic Losses by Natural Disasters 1995 - 2004
Source: EM-DAT, CRED

1.2 Necessity of Flood Forecasting

In order to reduce flood disasters especially human casualties, early warning system plays a crucial role. The worldwide growing flood disasters are generally attributed to two main reasons; increase in extreme weather phenomena that are said to be associated with global warming, social factors such as higher concentrations of populations and assets in urban areas, uncontrollable urbanization into flood-prone areas, the declining efficacy of disaster response in changing society. In developing countries, in particular, large populations are often obliged to relocate to areas with high risk of flooding for socially-driven reasons such as poverty and unemployment. And the victims of flooding are inevitably the more defenseless elements of society such as children, the elderly and women.

Unlike earthquakes which occur all of a sudden and are difficult to predict, evacuation from flooding along with other forms of water-related disasters such as tsunamis and debris flow, is possible if adequate actions based on correct judgment of disaster information are taken before the overhanging disasters materialize, which is the field flood forecasting is required.

According to UN-ISDR, whole early warning system is composed of four elements; “Risk Knowledge”, “Warning Service” to which flood forecasting belongs, “Dissemination of Understandable Warnings to Those at Risk” and “Response Capacity – Knowledge and Preparedness to Act”.[3] With respect to this four elements, proper actions have seldom been taken particularly against unprecedented natural phenomena. This is because people, in such occasions, tend to fail to be fully aware of the extent of the risk and their destroying power even at the moment they are most likely to be involved in it. Therefore flood forecasting can plays its role only with balanced linkage of the above four elements.

2. Flood Forecasting at Present

Flood forecasting constitutes an integral part of whole early warning system. Effective flood forecasting requires accuracy, timely delivery, understandability, and so on. Concerning accuracy and timely delivery, realtime hydrological data transmission is requisite as well as suitable run-off models. Among various types of data transmission, telemetry is generally used to send hydrological data from ground stations on realtime basis. Other means such as radio, telephone and mobile phones are also being used as practical ways in river basins without telemetry.

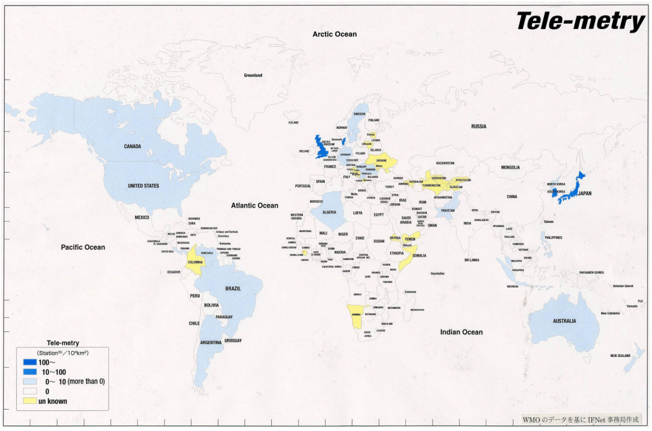


Fig.3 World Telemetry Distribution
Source: WMO

According to the World Meteorological Organization (WMO), as of 1995 it was no more than 30 countries that possessed telemetry, most of which were developed countries as shown blue/right blue color in Fig.3.
Although the number of countries is undoubtedly bigger at the moment with past/ongoing efforts to introduce ones; nevertheless, there are obstacles for telemetry to be a worldwide prevailed system.

The difficulty in introducing telemetry in developing countries can be largely attributed to the following two factors:

- Even if telemetry is introduced, keeping it in proper running order isn't easy due to budget restriction for operation and maintenance, availability of spare parts, geographical difficulties with dispersed locations of telemetry stations throughout large river basins and so on.
- Diplomatic difficulties lie in setting up telemetry over a whole transboundary river basin extending several countries.

3. Possibility of Satellite Rainfall

3.1 Present Satellite Rainfall Observation and Data Delivery

The launch of Tropical Rainfall Measuring Mission (TRMM) satellite, joint project of NASA and JAXA, in 1997 was epoch-making to have made the use of satellite rainfall data in practical disaster management conceivable. The advantage of satellite rainfall observation is that it can analyze the three dimensional rainfall structure of typhoons, rain front, etc. and has no influence of topographical conditions[4)]. While in disaster management, continuous rainfall data delivery system is requisite, which has been realized by the current satellite rainfall observation system by TRMM, a few other orbital satellites and geostationary satellites on the equator since 2002, of which data set product called "3B42RT" is available on NASA website.

The 3B42RT is given as binary mesh data corresponding to area average hourly rainfall for each mesh. The specifications of 3B42RT are as follows:

- Mesh Size: 0.25 degrees of latitude/longitude (square of approximately 30km by 30km on the equator, and rectangle of approximately 30km by 20km on 40° N for example)
- Global Coverage: between 60° N and 60° S longitude
- Data Delivery: every 3 hours on near realtime basis with several hours time lag

In applying 3B42RT to some practical uses, it should be noted that 3B42RT is produced only by satellite rainfall observation without any calibration using ground rain gauge data etc. In addition the quality and accuracy can vary day by day due to the variance of orbit of each satellite which passes over a river basin only several times a day, and each mesh data isn't necessarily equal to point data of ground rain gauge. Therefore verification of satellite rainfall data in such way as comparing with ground or radar rain gauge data is necessary.

3.2 Global Precipitation Measurement (GPM)

Present satellite rainfall observation system is planning to be strengthened based on the successful achievement of current system into one called Global Precipitation Measurement (GPM), joint initiative by NASA, JAXA and other space agencies. GPM will consist of one core satellite and eight constellation satellites and be expected to deliver more precise data covering the whole globe[4)]. Although the schedule of GPM is largely affected by US budgetary situation, the GPM core satellite is due for launch in 2012.

3.3 Applicability of Satellite Rainfall in Flood Forecasting

As is naturally supposed from the specifications of 3B42RT, the applicability of satellite rainfall in flood forecasting differs in the size of river basins. Therefore river basins are divided into "large" and "small" without strict definitions here for the sake of convenience.

1) Large River Basins

A large river basin is roughly defined here as one whose catchment area is far larger than 3B42RT mesh and upstream rainfall takes nearly or more than several days to reach downstream. For river basins of this size, satellite data could be informative in flood forecasting due to the following reasons:

- Although the data delivery of 3B42RT is near realtime basis with several hours lag and every three hours, not hourly, the influence of these is thought to be negligible because of much longer run-off period.
- 3B42RT is an area average mesh data of around 900 km^2 on the equator. The mesh size is far small compared with catchment areas so that the use of area average data doesn't neglect the topographical conditions of large river basins.

In addition the following conditions back up the effectiveness of satellite rainfall.

- In a river without telemetry, satellite rainfall can't perfectly make up for the absence of telemetry system, though, it can be precious hydrological information.
- In a transboundary river where data transmission across national boundaries is unlikely, satellite rainfall can be sole and valuable hydrological data source for upstream rainfall.

2) Small River Basins

A small river basin is roughly defined here as one of which catchment area is not so large compared with 3B42RT mesh and run-off period are not so long compared with the several hours time-lag of 3B42RT data delivery. For river basins of this size the applicability seems to be lesser due to following:

- Hourly maximum rainfall with realtime data transmission has significant meaning in flood forecasting in a small river basin owing to its swift run-off.
- Wider observation mesh doesn't sufficiently reflect the topographical variation of a small river basin but equalize it, which might not lead to a actual run-off simulation.

However satellite rainfall data has another possibility to complement existing flood forecasting system using its observation coverage off coast and information of three-dimensional rainfall structures.

3.4 Flood Situation in Bangladesh

One of probable areas meeting the conditions of satellite rainfall can be found in Bangladesh that has repeatedly suffered from catastrophic disasters mainly due to storm surge from Indian Ocean caused by cyclones and flooding brought by the three major rivers; the Gnages-Bramaputra-Meghna (GBM) River (Figure 4). While cyclone forecasting and warning system has been established, coping with flooding by the GBM river still has following challenges which at the same time support the effectiveness of satellite rainfall to the Bangladeshi situations:

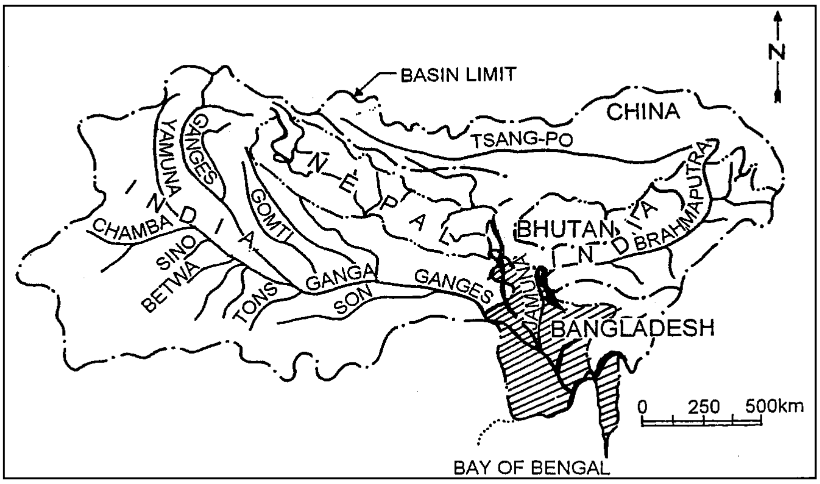


Figure 4 the Gnages-Bramaputra-Meghna (GBM) River
Source: JICA Report "Preliminary Study on Flood Forecasting and Warning System in Bangladesh"

- Most of the land is located in the downstream low-lying delta of the Gnages-Bramaputra-Meghna (GBM) River, the three major rivers which confluent with each other in the territory of Bangladesh creating flood-prone conditions.

- Bangladesh occupies no more than 10% of the GBM river basins that means most river waters originates in upstream countries having 90% of the GBM river basins.
- In addition upstream countries' hydrological data don't reach Bangladesh at present but for data of a small number of stations close to the border.
- The scale of the GBM river is too large to control floods by structural measures, so the timely and accurate flood forecasting is the key to reduce flood victims.

4. Trial Run of GFAS

4.1 Basic Idea of GFAS

1) Collaboration with Related Agencies

GFAS is an attempt to make the best use of satellite rainfall data observed by earth observation satellites in flood forecasting. GFAS is an Internet-based information system which converts the original binary data downloaded from NASA website into user-friendly forms such as global and regional rainfall maps, text data, heavy rain information by probability estimates etc. in order to provide existing flood forecasting system of another source of hydrological data. The basic idea of GFAS is collaborative activities between:

- Space agencies such as NASA, JAXA as satellite rainfall data providers,
- Infrastructure Development Institute-Japan (IDI) as system developer and operator,
- International Flood Network (IFNet) of which secretariat is placed in IDI, as a network for information distribution,
- Hydrological services/river authorities as responsible agencies for flood forecasting and warning.

Among the above combination, the role of IDI and IFNet is to connect space agencies and hydrological services/river authorities.

IFNet is an open free network established at the 3rd World Water Forum in Kyoto, Shiga and Osaka, Japan in March 2003. The objectives of IFNet is to promote and facilitate flood related activities by information sharing and exchange etc. The number of already registered participants amounts to over 440 of agencies, organizations and individuals.

2) Objectives of Trial Run

Due to the characteristics of satellite rainfall data as mentioned in 3.1, the effectiveness of its use has yet to be examined. Therefore the first launch of GFAS is called "trial run" aiming to verify how satellite rainfall represents actual precipitation and can play a part in flood forecasting.

In the case of the Tone River in Japan of which catchment area is 16,840km^2, the error of mean basin rainfall calculated for a typhoon using satellite rainfall from one by ground rainfall were 35% for one day rainfall and 5% for three-day.

3) Way of Information Delivery

In terms of the way of GFAS information delivery, GFAS provides two types of information; basic one open to public, and customized one prepared on request from hydrological services/river authorities. Although the main user of GFAS information will be hydrological services/river authorities, basic information GFAS is made public by posting it on to IFNet website for free access without password, because there might be other needs of this kind of information for other users/fields than flood forecasting. General information includes global rainfall distribution map and regional maps containing several countries/large river basins.

Beside these, customized information such as single river basin maps, e-mail notification of heavy rainfall, etc. is also provided on request from hydrological services/river authorities which are also registered IFNet members. The reason why single river basin maps aren't made public is that the effects of their publicity haven't fully been foreseen without due consideration for international relations.

4.2 Information Service

1) Basic Information

A trial run of GFAS has just started in April 2006. The following basic information is posted on IFNet website for free access:
http://www.internationalfloodnetwork.org/index.html

- Global map of daily and three-day rainfall, and their heavy rain area etc.
- Nine regional maps of daily and three-day rainfall, their heavy rain area etc.
- Text data of global daily raifall (1,440 x 480 mesh) and others

Figure 5 shows a global daily rainfall map which is produced at 00:00 GMT and renewed daily. Figure 6 is an example of regional map for South East Asia Region. Left side is a daily rainfall and right expresses areas of rainfall by blue and heavy rain area exceeding five-year return period, in this case, by red.

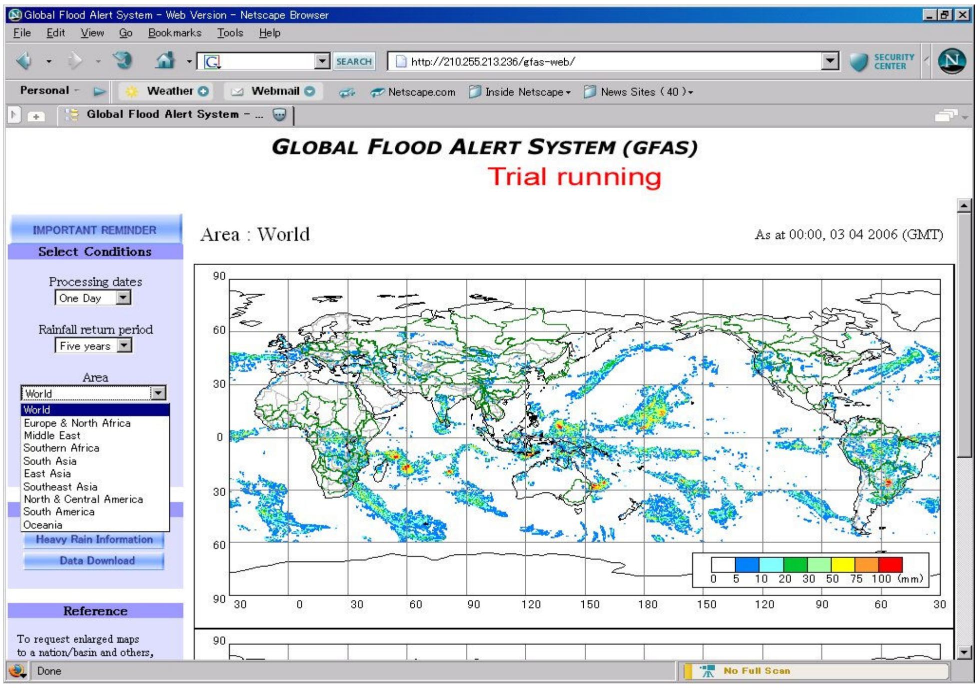


Figure 5　Global Daily Rainfall

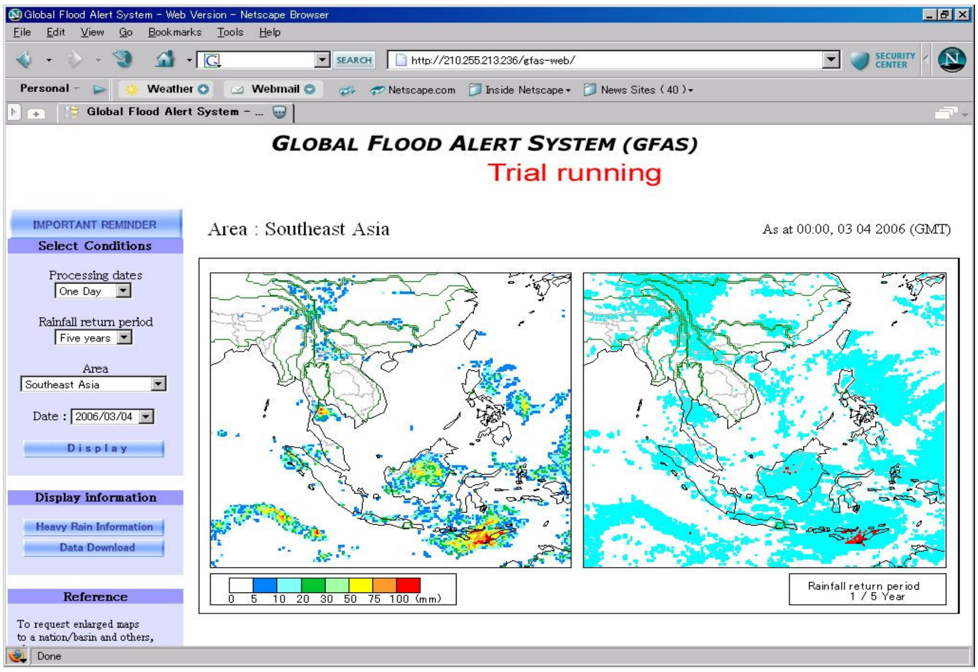


Figure 6 An Example of Regional Map

Figure 7 is probability rainfall of 10-year return period analyzed using satellite rainfall data. The map gives better expression of precipitation characteristics for each climate zone and topography on every part of the earth's surface including ocean areas. This information is used to detect heavy rain areas.

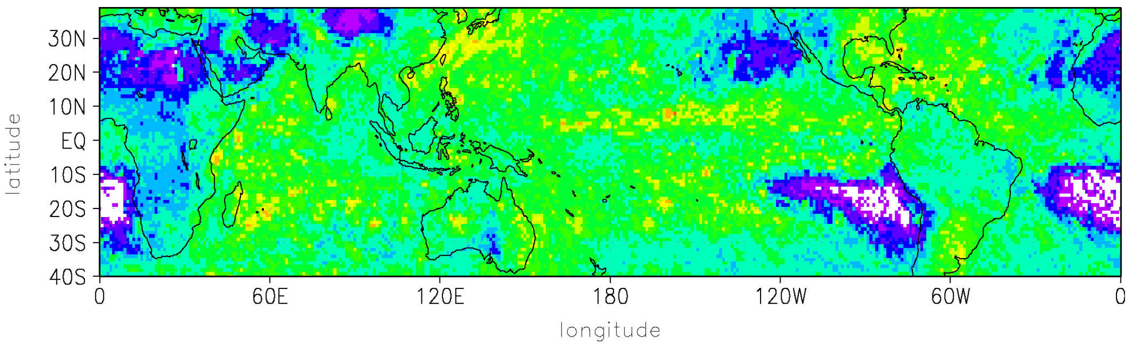


Figure 7 Probability Rainfall of 10-year Return Period

2) Customized Information

As mentioned in 4.1 3), customized information includes single river basin maps, e-mail notification of heavy rainfall, etc. which is prepared on request from hydrological services/river authorities of registered IFNet members. The operation of E-mail notification is that e-mails are automatically sent to the registered address when the mean basin rainfall of registered river basins exceeds a predetermined threshold (5-year or 10-year return periods). Since the responsibility for weather warning belongs to each liable meteorological agency, this alerting email is not so much warning as information. One organization in Thailand, one in Cambodia and two in Laos are ready to accept this service. A sample email is shown below.

Sample: Heavy rain information for ZZ basin.

Mean basin rainfall of YY mm/day exceeding 5 year return period rain was observed on (date). Please check on http://xxxxxxxxxxxxxxxxxxxxxxx

5. Future Activities

To improve newly launched system and further explore the possibility of satellite rainfall in flood forecasting, the following activities, through the delivery of GFAS information and users' needs/feedback, shall be continued:

- satellite data verification in foreign rivers,
- addition of GFAS menu,
- project finding and formulation to apply GFAS information to flood forecasting using suitable run-off model.

In addition, since the effectiveness of satellite rainfall in flood forecasting depends on the availability of satellite data with preferable specifications, communication about users' needs and expectations with space agencies has to be kept.

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