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Satellite-based assessment of flood risk and flood exposure

by

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Acknowledgement

The Integrated Flood Analysis System (IFAS) was developed by the ICHARM's Hydrologic Engineering Research Team, building on work under the International Flood Network (IFNet). Also, this team produced many of the analyses and observations presented in the present paper.

ICHARM

International Centre for Water Hazard and Risk Management was established in March 2006 under the Public Works Research Institute, Japan. ICHARM conducts research, training and networking as a contribution to prevention of water-related hazards and mitigation of water-related calamities. Among its various training activities is a 1-year MSc course in water-related risk management. International operation takes place in collaboration with UNESCO and WMO in support of the International Strategy for Disaster Reduction, the World Water Assessment Programme (WWAP), and the International Flood Initiative (IFI).
ICHARM serves as the secretariat for IFI and is a member of the APWF network of regional knowledge hubs.

Summary

Flood analysis requires rainfall data, water level data and flow data. The availability of such data is always less than ideal, and sometimes much less than ideal.

In recent years the ready (and free) availability on the Internet of global satellite-based rainfall data offers a spectacular opportunity for enhancing the coverage and validity of traditional rain gauges.

The present paper describes the use of satellite-based rainfall data as a supplement to, or even (if need be) a substitute for traditional hydrological measurements.

The quality of satellite-based rainfall data is high in terms of coverage but low in terms of accuracy (and resolution of peak events). This is complementary to the quality of ground-based monitoring networks, where the quality is high in terms of accuracy but low in terms of coverage.

A powerful data basis can be achieved by combining the two types of data, adding their respective advantages while neutralizing their weaknesses.

To enhance the accuracy of satellite-based rainfall, ICHARM has been developing correction method of satellite-based rainfall comparing ground-based rainfall data. Moreover, ICHARM provided flood forecasting system “Integrated Flood Analysis System (IFAS)” using satellite-based rainfall and its correction method.

Historical analyses, important for design purposes and risk mapping (and hereby land use planning), require a high validity but are less sensitive to time resolution and insensitive to transmission delays. For applications in urban areas, the space resolution and peak intensities are of a particular importance. Real-time and forecasting applications are less sensitive to validity, but highly sensitive to time resolution and transmission delay, and a good area coverage is needed.

Hence, the two types of data can highly add value to each other, irrespective of the scope of the analysis.

Acronyms and abbreviations

APWF:	Asia-Pacific Water Forum
DEM:	Digital elevation model
ICHARM:	International Centre for Water Hazard and Risk Management (Tsukuba City, Japan)
IFAS:	Integrated Flood Analysis System
IFI:	International Flood Initiative
WWAP:	World Water Assessment Programme

1 Introduction

Flood analysis requires rainfall data, water level data and flow data. The availability of such data is always less than ideal, and sometimes much less than ideal.

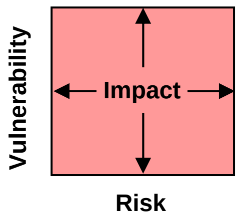
The present paper describes the use of satellite rainfall data as a supplement to, or even (if need be) a substitute for traditional hydrological measurements.

2 Background

Floods can be caused by marine storm surge affecting coastal areas; and/or inflow from upstream parts of the river basin; and/or direct rainfall.

The impact of floods can be illustrated as *risk x vulnerability.*

Figure 1: Impact of floods



The *vulnerability* to floods depends on

- land use (including population density, buildings, production plants, infrastructure and ecosystems);
- awareness and preparedness (including forecasting); and
- options for response & mitigation;

... all of which can be planned for & managed.

Apart from exposure to rainfall and inflow, the *flood risk* depends on

- the drainage capacity;
- the flow resistance - upstream & downstream;
- the storage capacity; and
- structural protection;

... all of which respond to intervention.

The flood risk is influenced by

- the climate (which can fluctuate over small, medium and long periods of time);
- morphological changes of the river system, whether of natural or human origin; and
- any human intervention in the river system that changes the runoff, the flow resistance, or the wet season flow itself.

Comprehensive deforestation can occur due to forest fires and human intervention. Deforestation can increase the flood risk, both by changing the runoff pattern and by increasing the sediment yield and hereby increase the flow resistance in the river system.

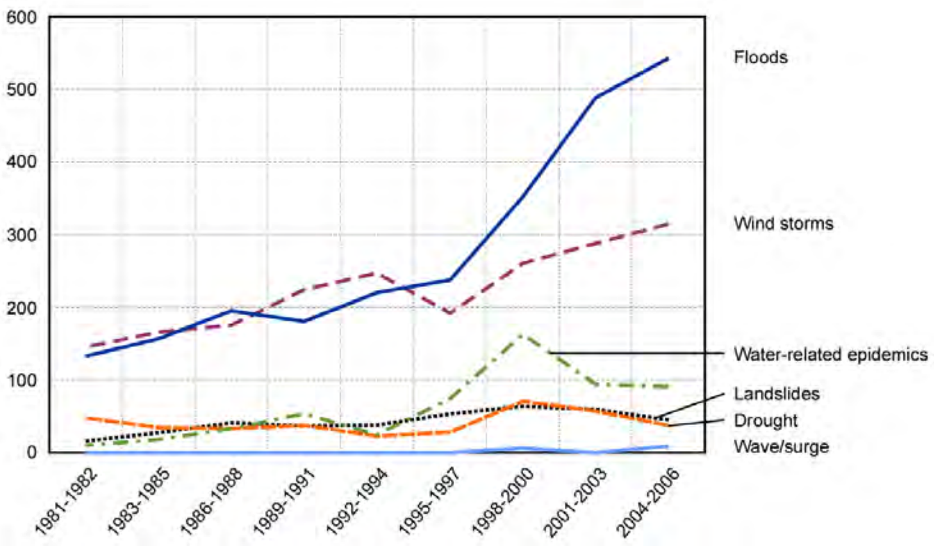
Dredging of navigation channels and regulation of bends can at the same time increase and reduce the flood risk at different places. Likewise, a flood protection scheme can reduce the flood risk at one place while increasing it at other places.

Earthquakes can change the flood risk by changing the planform of the river, and by releasing large pulses of sediments. In some places, including some major towns, the flood risk can be enhanced by irreversible subsidence caused by excessive groundwater withdrawal.

Both the risk and the vulnerability are increasing over time. Flood-related impacts are most severe in Asia (while drought-related impacts are most severe in Africa).

Good knowledge about flood risk and exposure is an important part of the basis for appropriate planning and decision-making, as clearly demonstrated by a simple comparison between a flood risk map and a land use map.

Figure 2: Water-related disasters



3 Flood analysis practicalities

Data

It is quite normal that the data availability is affected by practical implications such as

- lack of real time rainfall data which covers whole basin;
- lack of elevation data;
- lack of river network data, or low validity of such data during extreme events (due to overland flows);
- imperfect network density in the drainage basin (for example for steep mountain sides with high rainfall intensity);
- lack of coverage of adjacent seas (from where rainfalls may approach);
- imperfect general operation and maintenance of gauges and monitoring stations;
- imperfect rating curves (for example not representing extreme events, or having changed in the course of time); and
- imperfect data coverage and data transmission during extreme events (for examples due to malfunctioning or lost gauges).

Tools

Tool implementation and use may be affected by practicalities such as

- hardware and connectivity requirements;
- procurement and operation costs; and
- resource requirements in terms of skills and capacity.

Tools for flood analysis are in a state of rapid development, offering improved performance and better value for money.

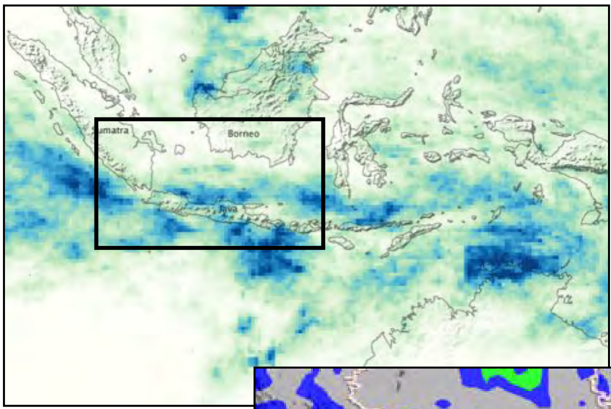
4 Satellite-based and gauge (ground-based) data

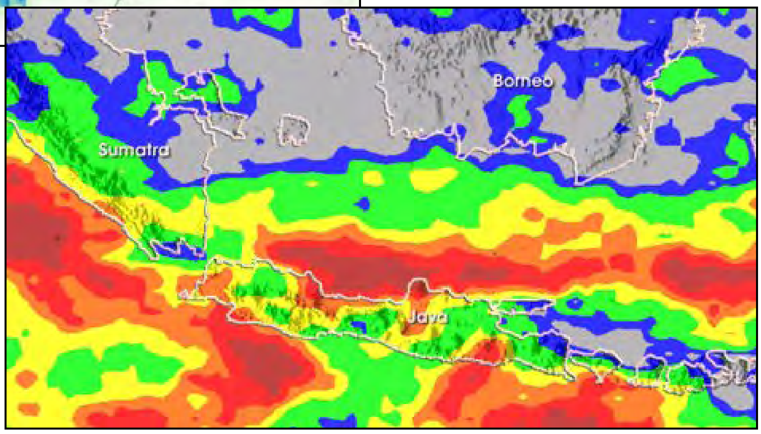
In recent years the ready (and free) availability on the Internet of global satellite-based rainfall data offers a spectacular opportunity for enhancing the coverage and validity of traditional rain gauges.

Table 1: Real time rainfall data by satellite

Name	3B42RT	CMORPH	QMORPH	GSMaP
Owner	NASA	NOAA	NOAA	JAXA
Coverage	60° N - 60° S	60° N - 60° S	60° N - 60° S	60° N - 60° S
Spatial resolution	0.25° (25 km)	0.25° (25 km)	0.25° (25 km)	0.1° (10 km)
Time resolution	3 hours	3 hours	30 minutes	1 hour
Delivery delay	10 hours	15 hours	2.5 hours	1 hour
Data archive	Since Dec 07	Since Dec 02	Previous 2 days	Since Dec 07

Figure 3: Accumulated rainfall distribution based on satellite imagery

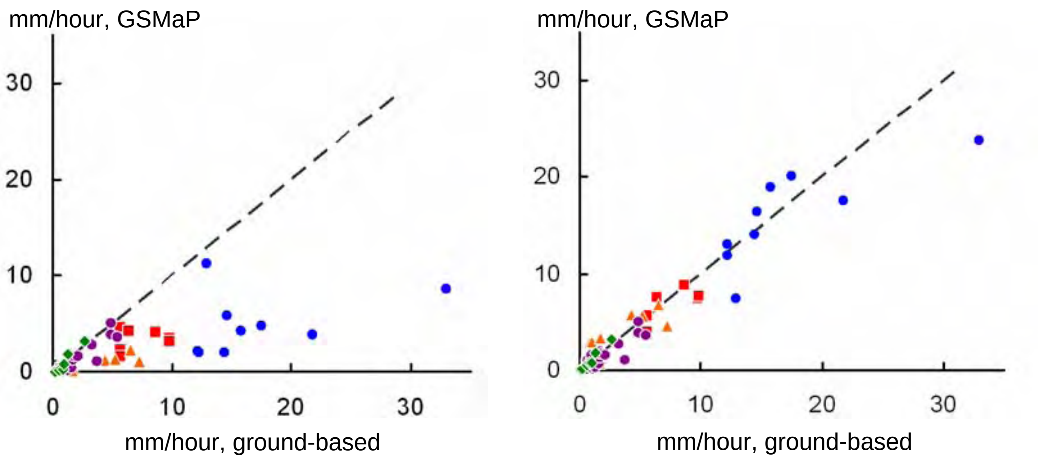




NASA data for the period from 24 Dec 2007 to 2 Jan 2008, where Java was hit by floods

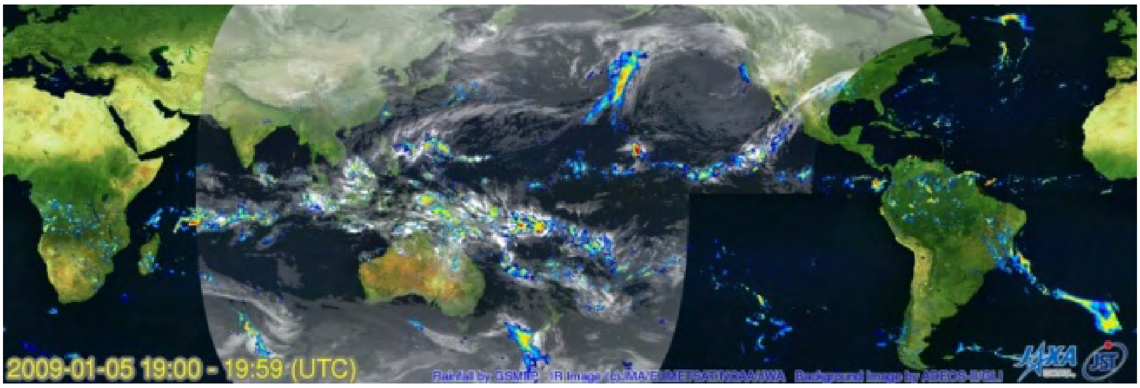
In general, satellite-based rainfall underestimate, a careful calibration is needed to use input data for flood forecast with local ground-based data, as illustrated in the figure below.

Figure 4: Calibration of satellite-based rainfall data



Legend: ● Japan 2004, hourly values; ■ USA Aug 08 (Katrina), hourly values; ▲ Nepal 2004-06, daily values; ● Bangladesh 2004, daily values; ◆ Argentina 2003, daily values

Figure 5: A GSMaP image



The quality of satellite-based rain data is high in terms of coverage but low in terms of accuracy. This is complementary to the quality of ground-based monitoring networks, where the quality is high in terms of accuracy but low in terms of coverage. A particularly powerful data basis can be achieved by combining the two, adding their respective advantages while neutralizing their weaknesses.

Other (global) data sets relevant to flood forecasting model are available from satellite monitoring, as listed in the following table. Taking in these data, IFAS can automatically create run-off analysis model and estimate parameters for flood forecast.

Table 2: Examples of global data tables

Type	Product	Provider
Elevation	Global elevation data (1 km grid)	ISCGM
	GTOPO30 (1 km grid)	USGS
	Hydro1k (1 km grid)	USGS
	Shuttle Radar Topography Mission (90 m grid)	NASA
Land use	Global Land Cover Characterization (GLCC)	USGS
	Global land cover	ISCGM
	Global land use	ISCGM
Geology	Geology	CGWM
Soil	Soil texture	UNEP
	Soil moisture capacity	UNEP
	Soil depth	GES

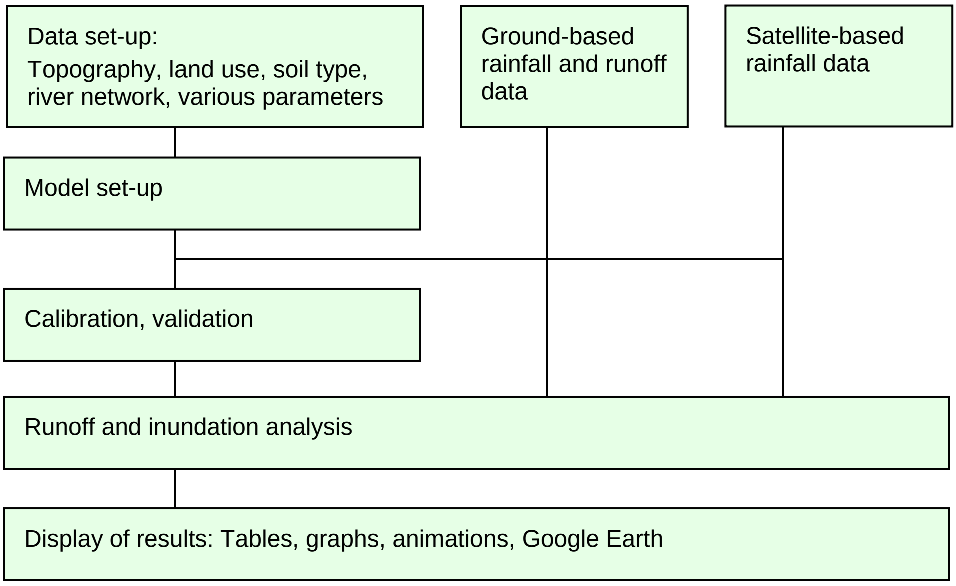
5 The Integrated Flood Analysis System (IFAS)

The IFAS has been developed by ICHARM as a practical tool for flood analysis. The system is freely available from the ICHARM website. It features

- interfaces to both ground-based and satellite-based rainfall data;
- GIS functions to establish flood-runoff models;
- a default runoff analysis model; and
- output routines and interfaces, including Google Earth.

The data flow is summarised in the following figure.

Figure 6: Calculation routine



6 Discussion

The complementarity of rainfall data from satellites and ground-based rain gauges is summarised below.

Table 3: Quality characteristics of rainfall data

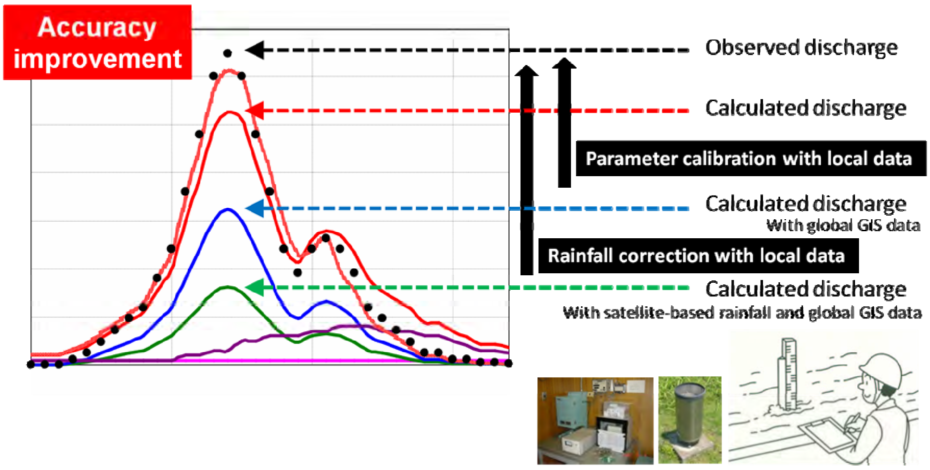
Aspect	***Satellite-based rainfall***	***Rainfall gauge data***
Coverage	'Global' (60° N - 60° S)	Depending on network
Precision (mm/hour)	Millimetres	Millimetres
Time resolution	Hours	Minutes
Area resolution	10-25 km	Depending on gauge density
Transmission delay	4 hour or more	Minutes

Due to the limited time and area resolution, peak intensities (of rainfall and the corresponding, calculated runoff) are described with a poor quality if only original satellite-based data are used.

The complementarity between the two types of data is highly relevant for flood analyses.

The quality of the satellite-based data will improve in the course of time. To enhance the accuracy of satellite-based rainfall, ICHARM has developed a correction method that compares satellite-based and ground-based data. This correction method is implemented in the IFAS.

Figure 7: Accuracy improvement process using local data



Historical analyses, important for design purposes and risk mapping (and hereby land use planning), require a high validity but are less sensitive to time resolution and insensitive to transmission delays. Real-time and forecasting applications are less sensitive to validity, but highly sensitive to time resolution and transmission delay.

Applications will often be at the basin level and/or covering urban areas (where the space resolution and peak intensities are of a particular importance). Again, the data types are complementary, in terms of time and area resolution.

Hence, the two types of data can highly add value to each other, irrespective of the scope of the analysis.

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If you want to know more ...

... please refer to the ICHARM website, www.pwri.gov.jp

... and the website of the International Flood Initiative: www.ifi-home.info

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