Application of Satellite Information for Flood Risk Reduction in Mekong River Basin

Perapol BEGKHUNTOD

Regional Flood Management and Mitigation Center
Mekong River Commission
P.O. Box 623, # 364, Preah Monivong Blvd, Phnom Penh, Cambodia

Abstract

The Flood Forecasting and River Monitoring System in the MRC have over the years been improved to provide timely and accurate river forecast to the member countries in order to reduce the vulnerability of floods and droughts. The innovative of rainfall which derived from cloud top temperature of cloud images from meteorological satellite and merged with observed rain gauges have been the main input in flood forecast system in MRC. Satellite-based precipitation algorithms developed in 1990's by scientists who are involved in microwave and remote sensing, both from ground-based observations and remote sensing from satellites and spacecrafts, may be the main source of rainfall data due to the scarcity of hydrometeorological networks, long delays of data transmission, and absence of data sharing in many transboundary river basins. A merged satellite- and surface-based rainfall estimation (RFE) technique to enhance the knowledge of collecting precipitation was developed at the NOAA Climate Prediction Center (NOAA/CPC) and has been used globally. The RFE brings value-added information to rain-gage interpolations as a near real time rainfall dataset. Tropical Rainfall Measuring Mission/Precipitation Radar (TRMM/PR) jointed project between National Aeronautics and Space Administration (NASA) and Japan Space Exploration (JAXA) has contributed an extraordinary amount of information on rainfall around the tropical world, including the Mekong basin. Satellite data products complement and enhance conventional rainfall data collection. In addition to disaster response, USAID Office of U.S. Foreign Disaster Assistance (USAID/OFDA) provides support for Regional Flood Management and Mitigation Center to mitigate the adverse impacts of floods in Mekong River Basin through strengthening flood forecasting and warning capacity of regional and national agencies. An early warning system and preparedness plan are vital tools in reducing loss of life and socio-economic impacts of floods. Improvement of flood forecasting operations requires continuous efforts in many fields, including river monitoring network, data collection, transmission and processing; development of advanced forecasting techniques, communication network and assessment of forecasts.

Canadian Space Agency (CSA) have also provided time series of radar imagery from RADARSAT-1 with a detailed and accurate information of the unfolding flood events in the lower portion of the Mekong basin and around the Great Lake. The radar sensor is very good at distinguishing land and water boundaries.

This presentation illustrates an integrated approach using RFE, TRMM/PR and RADARSAT to flood mitigation and management, crucial to reducing vulnerability to floods and other hydrometeorological extremes.

Keywords: flood forecasting; Mekong River Commission; satellite rainfall estimate; early warning system; Mekong River Basin.

1. Background

Flooding in the Mekong River Basin is a recurrent event affecting the entire basin. Almost every year, it takes away a lot of lives and causes damage to infrastructure, agricultural, industrial production and severely affects socio-economic development. Recurring flood of the magnitude and frequency observed in the region is significant impediment to a more rapid development in the Mekong basin.

The 1966 severe flood called for the establishment of the flood forecasting system of the Lower Mekong Basin. At the beginning of the 1970's the existing regional forecasting system with application of advanced computer techniques and mathematical models was set up in the Mekong Secretariat. Following the floods in 1978 and 1981 the forecasting system was expanded to cover major tributaries.

The 2000 flood caused of US$ 400 million worth of damage and 800 casualties, mainly children. At the Phnom Penh station, water level was recorded with a return period of 70 years. The Mekong River Commission (MRC) Council, at its annual meeting in October 2000, called for immediate action for the establishment of a basin-wide Flood Management and Mitigation (FMM) in the Mekong River Basin. In November 2001, the FMM Strategy (FMMS) was approved by the MRC Council and used as a basis for the development of the FMM Programme (FMMP) adopted in November 2002. The overall objective of the FMMP is to prevent, minimize and mitigate people's suffering and economic losses due to floods, while preserving the environment benefits of floods. It consists of five components: 1. Establishment of the Regional FMM Center (RFMMC), 2. Structural measures and floods proofing, 3. Mediation of trans-boundary flood related issues, 4. Flood emergency management, and 5. Land use management. The FMMP is based on priorities agreed upon by the four MRC member countries and on the strategic roles of the MRC. The component of the programmes are related to each other and link to MRC's existing programmes, and will contribute to MRC's overall role in knowledge base development, capacity building and regional cooperation.

2. MRC Flood Forecasting and Its Operation

It consists of three main components: 1. Data collection and transmission, 2. Forecast operation, 3. Forecast Dissemination.

In close collaboration with the four National Mekong Committees (NMCs) and the national concerned line agencies, both historical and operational hydro-meteorological data from the member countries are delivered to the MRCS for the operational forecast regularly in accordance to the Procedures for Data and Information Exchange and Sharing (PDIES) of the MRC (MRC, 2001). The operational data collected for flood forecasting and river monitoring activities in the MRCS are given in Table 1.

Table 1 – Operational data delivered regularly to the MRCS

Item	Wet season (Jun – Oct)	Dry season (Nov – May)
Forecast Activity	Flood Forecasting	River Monitoring
Data delivery to MRCS	Daily	Weekly
No. of days of forecast	5-day forecast	7-day forecast
Water level data	44 stations (included 2, from China)	19 stations
Rainfall data	44 stations (included 2, from China)	19 stations
Forecasting point	21 stations	19 stations

Apart from the data received from the countries, the interpretation and analysis of other available weather data such as satellite images, rainfall estimation and forecasts from various sources, including those from US Geological Survey/National Oceanic and Atmospheric Administration (USGS/NOAA), Thai Meteorological Department (TMD) are also carried out. Figure 1 shows an example of rainfall estimates and forecast from USGS/NOAA used for the regional forecasting.

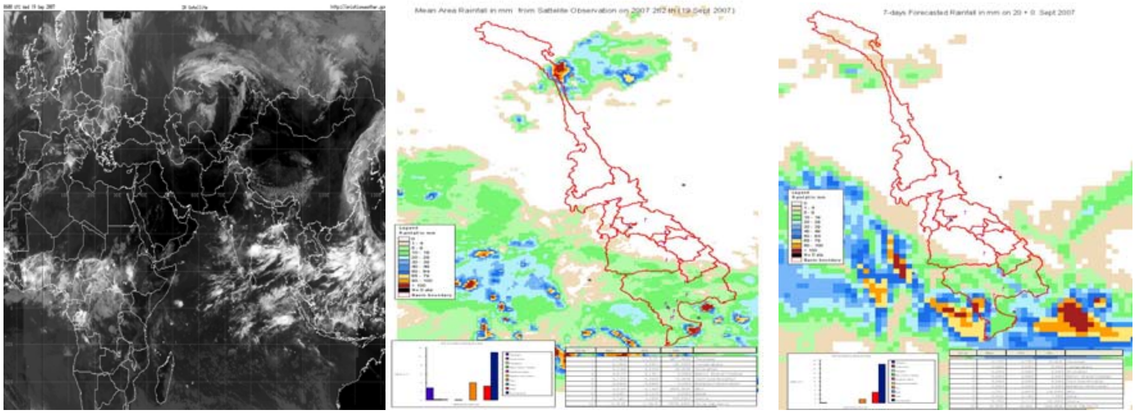


Figure 1 Cloud image from Meteorological Satellite and Rainfall estimates from USGS/NOAA (left: Infrared images from GOES-E on September 19, 2007, 13:00 LT., middle: A merged-satellite rainfall estimates and observed-rainfall from USGS/NOAA in 10 x 10 km. grid base on September 19, 2007, right: Rainfall forecast from USGS/NOAA in 0.375° x 0.375° grids on September 20, 2007.

A variety of forecasting tools is applied to forecast water levels and discharges. The Streamflow Synthesis and Reservoir Regulation (SSARR) model, developed by the US Corps of Engineering, has been operational more than three decades. At present, the SSARR model is applied to the upper reaches (from Chiang Saen to Pakse) while regression models are used for the lower reaches from Strung Treng to Tan Chau/Chau Doc, including the mainstream of Bassac and the Tonle Sap.

The next flood season in 2008, RFMMC will operate flood forecasting by URBS Model, a networked runoff-routing, which has been existence since 1989. It has been built on the work of earlier rainfall runoff models used in Australia. URBS is currently used by the Bureau of Meteorology in Australia for real-time flood forecasting in a number of States and Territories. Full details of the model are given in Carroll (1999).

The routing variables used by URBS are, stream length, catchment area, channel slope, catchment slope, fraction urbanized (various degrees), fraction forested and channel roughness. The model requires that at least stream length be specified to define the extent of catchment and/or catchment routing. All other variables are included optionally in the modeling process at the discretion of the modeler.

URBS estimates flood hydrographs by routing rainfall excess through a module representing the catchment storage. Rainfall excess is first estimated from rainfall data using one of several loss modeling techniques. It is then applied to the runoff routing component of the model to compute the surface runoff hydrograph. Baseflow is estimated separately and added to the surface runoff hydrograph to provide the total catchment hydrograph. Although the model does not have an automatic calibration algorithm, the level of effort required to calibrate a URBS model is relatively low.

In the present, the forecasted water levels and discharges are available for five-day ahead during the wet season and seven-day ahead during the dry season. For further actions on flood preparedness and low flow counter-measures in a timely manner, the water level forecast bulletin, forecasted discharges in tabular form and the water level hydrographs at key stations along the Mekong mainstream are sent regularly to the concerned parties via e-mail and published on the MRC website (www.mrcmekong.org) by 10:00 a.m. local time.

3. Application of Satellite Data Products for Flood Risk Reduction

3.1 Weather Satellite and Satellite Rainfall Estimates (SRE)

The weather satellite system is composed of two types of satellites, so-called geo-stationary satellites and polar-orbiting satellites. A fleet of both types of satellites is necessary for complete worldwide monitoring and for making reliable weather forecasts. Weather observations over the Mekong Basin are made on a regular basis by a number of weather satellites, for example the Japanese MTSAT satellite, the American NOAA GOES satellite, the Chinese Fungyun (FY) satellite, and the Russian/Indian Electro satellite.

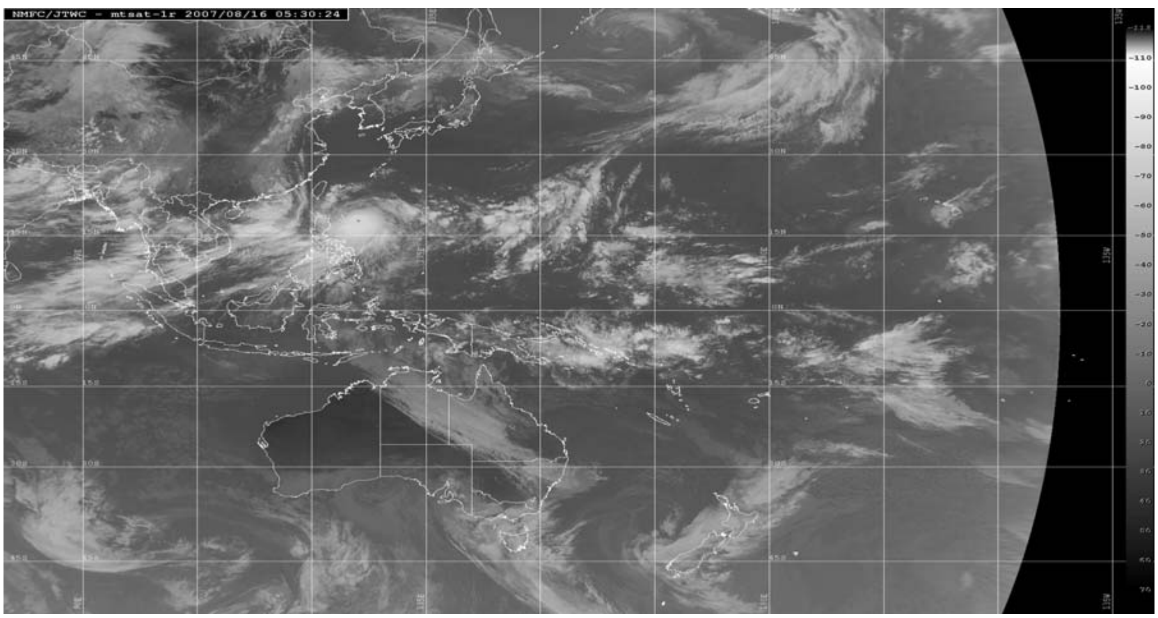


Figure 2 Infrared weather satellite image of Asia, Pacific and Australia taken on August 16, 2007 at 053024 GMT. Super Typhoon “SEPAT”(0709) centered at the east of Luzon Island, Philippines.

The infrared picture in Figure 2 from the Japanese MTSAT geo-stationary satellite measures the temperature of cloud tops, which can be used to determine their height. The white clouds are colder than the grey clouds. The spatial detail is approximately 5 km because of their long distance of ~36,000 km away from the Earth surface. Infrared images can be recorded during the day and at night, whereas visible pictures can only be made during daylight hours. Coastlines and lines of latitude and longitude are added for better orientation. Images are frequently updated – often on an hourly basis – and displayed on popular web sites of various meteorological services around the world.

Precipitation estimates for the Mekong River Basin and Hindu Kush region of southern Asia have been produced daily at the NOAA Climate Prediction Center, in association with the USAID's Asia Flood Network since early 2001. The precipitation estimation algorithm used is derived from the NOAA CPC RFE2.0 methodology, originally developed for hydrometeorological monitoring over Africa. The method combines satellite-based infrared and microwave rainfall estimation data with ground-based rain gauge inputs to produce daily rainfall grids at a resolution of 10 km. The datasets are shown in Figure 3 and 4 for satellite rainfall observed and forecasts in August 2007, respectively.

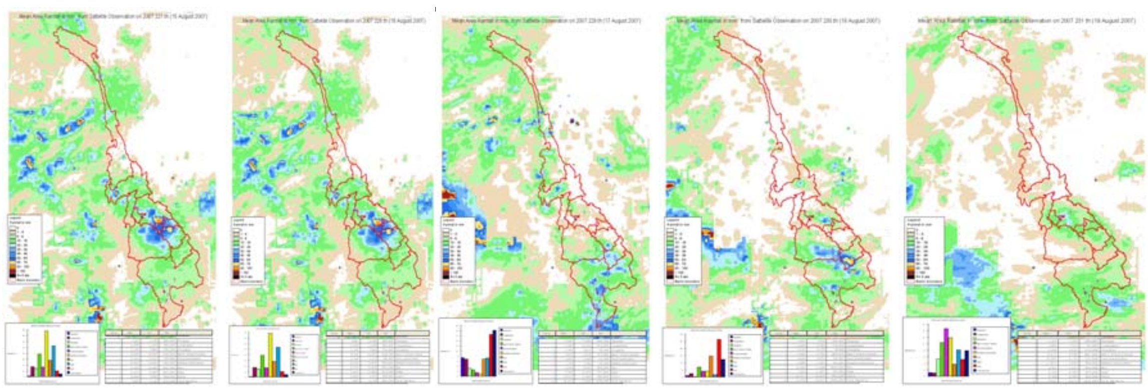


Figure 3 Satellite rainfall observed produced by NOAA CPC for MRCS at 10 km x 10 km resolution during August 15-19, 2007 (dated from left to right).

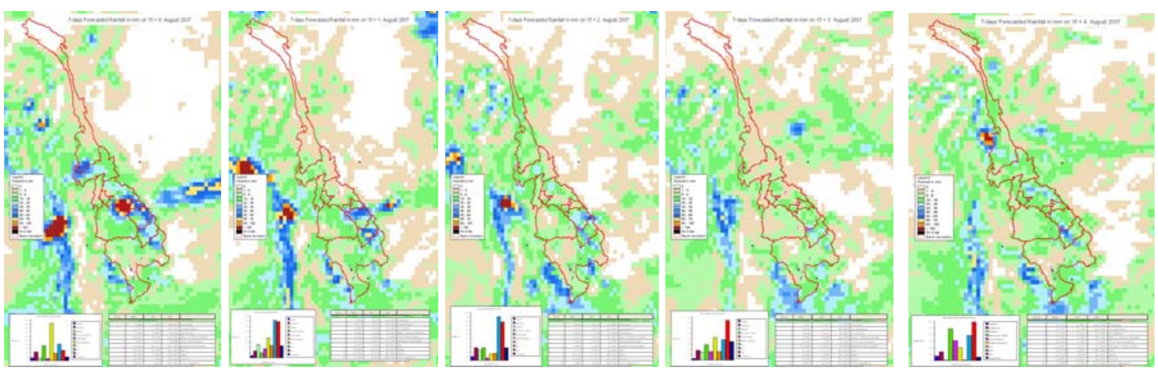


Figure 4 Satellite rainfall forecasts produced by NOAA CPC for MRCS at 40 km x 40 km resolution during August 15-19, 2007 (dated from left to right).

3.2 Conventional Rainfall Data from TRMM/PR

Tropical Rainfall Measuring Mission (TRMM) satellite is scheduled to operate until the end of this decade and Global Precipitation Measurement (GPM) mission will be the next generation of TRMM. Data which sends back to the Earth by TRMM can fill many gaps in our understanding of rainfall and its variation, its intensity and its areal coverage. Furthermore, the critical onset of large annual circulation regimes, such as the Asian summer monsoon, can be more thoroughly observed and studies using monthly or yearly time series as well as near-real time precipitation maps that are distributed every three hours over the internet, (http://trmm.gsfc.nasa.gov).

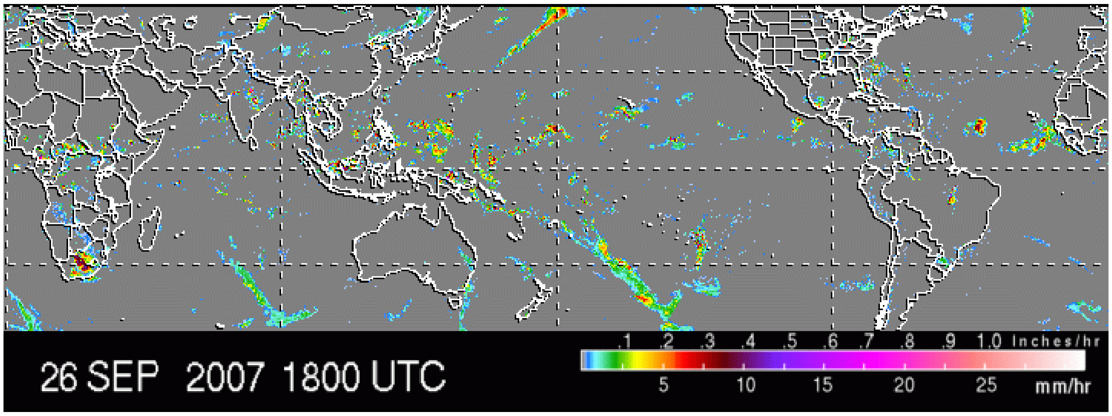


Figure 5 3-Hourly Global Rainfall products from TRMM during 15-18 UTC on 26 September 2007.

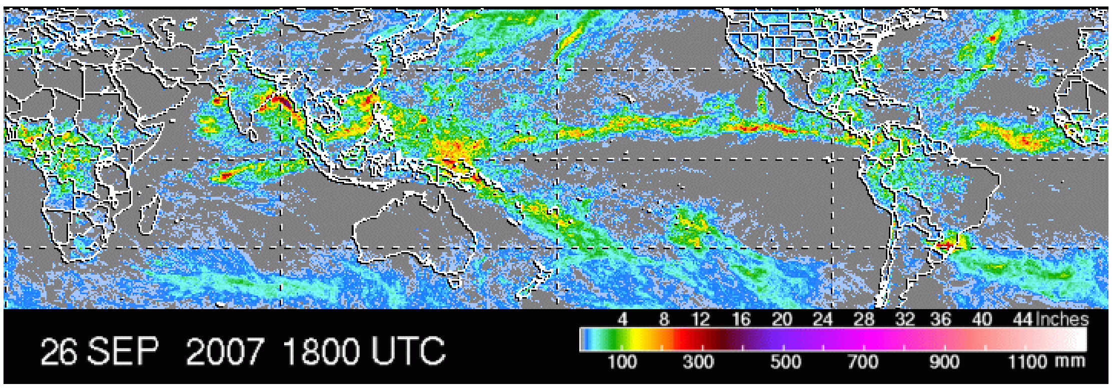
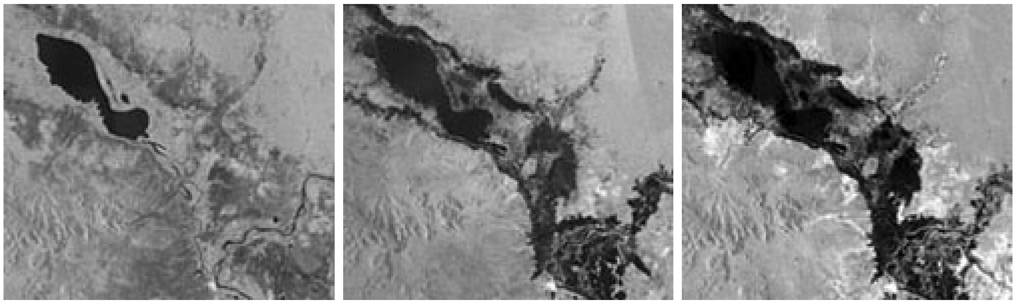


Figure 6 Weekly Global Rainfall Accumulation from TRMM during 20 September 2007, 1800 UTC to 26 September 2007, 1800 UTC.

3.3 RADARSAT Imagery for Flood Inundation Mapping

Monitoring Earth from Space is very effective way to better understand vital environmental issues such as climate changes. Information from Earth observation satellites provides important information to better protect the environment and to manage the natural resources.

For many emergency response organizations around the world, the Canadian RADARSAT-1 has emerged as a reliable tool for flood management activities. It has been used in the Mekong basin for flood monitoring experiments since 1999. RADARSAT-1 can acquire imagery on relatively short notice. Radar signals of water surfaces provide a very dark signature and contrast against surrounding land use. Conversely, there are strong radar returns and very bright image tones in the October 2000 image; these correspond to flooded rice corps. The spatial resolution of the original radar imagery is approximately 50 m. Example of radar images as shown in Figure 7. The interpretation map in Figure 8 shows a comparison of the maximum flood water extend measured during 1999 (red outline; radar image not shown here) and 2000 (green areas; based on October radar image shown here). Clearly, the extending of the 2000 flood exceeded that of the previous year.



March, 1999 August, 2000 October, 2000

Figure 7 Radar images from RADARSAT over Great Lake (Tonle Sap) (Courtesy of MRCS/CSA)

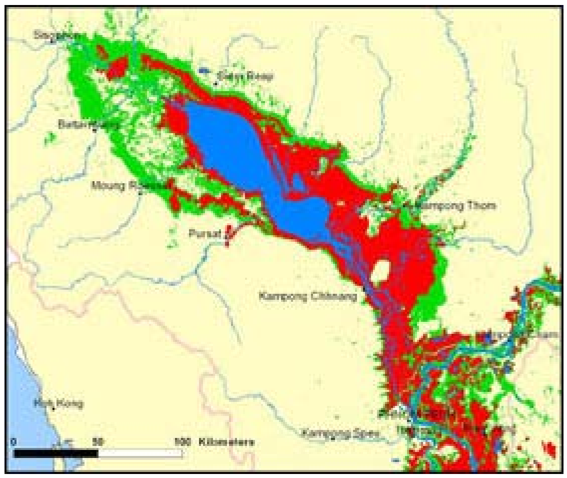


Figure 8 Comparison of the maximum flood extend measured during 1999 and 2000.

The time series of RADARSAT imagery can show the progress of the flood as well as the receding flood. The RADARSAT-1 radar sensor can also image smaller areas at higher spatial resolution, typically around 10 m.

4. Conclusions

The existing MRC Forecasting System was adequate in the past. However, rapid population growth in the region, intensification of agriculture, climate change, changes in land use and river morphology, and rapid technology development makes it imperative that the system will be upgraded, and a forecasting system, based on modern technology combined with a more effective warning system will be installed.

Satellite information in various kinds of products; weather satellite imagery (cloud images), satellite rainfall estimates (3-hourly rainfall, daily rainfall and weekly rainfall derived from microwave remote sensing), Earth observation satellite (environment and natural resources), are very important for flood management and mitigation, particularly flood risk reduction in the Mekong basin.

State of the art technology and perfect forecasts alone cannot save lives and property unless forecasts and warning reach the populations at risk with sufficient lead time to take appropriate measures to reduce the impact of disasters.

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