Application of Integrated Flood Analysis System (IFAS) for
Dungun River Basin

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Abstract. The Northeast monsoon happening during the months of October until January is the
major rainy season found in the eastern part of Peninsular Malaysia. The Dungun river basin
(1,858 km²) is exposed to this season thus experiencing characteristically regular flooding due
to the prolong rainfall events. The annual rainfall over the river basins are 2,880 mm with great
proportion falling in the months of December (19.4%). This study is to apply the Integrated
Flood Analysis System (IFAS) model which Dungun river basin has been chosen for this study
as the catchments have range of flood and relevant data that can be used to develop the model.
The satellite data used in this study is provided by JAXA Global Rainfall Watch. The main
feature of this real-time flood analysis model is the satellite-based rainfall data input employed
during the model creation phase. The performance of the model for the river basins from
satellite and ground-based rainfall data are compared using three error analysis methods.

1. Introduction
Flood has become regular disaster as it happened almost every year in different states. The northeast
monsoon, prevailing between November and February, brings heavy rainfall as much as 610mm in 24
hours in extreme cases predominantly to the east coast of Peninsular Malaysia and to Sabah and
Sarawak [1]. Rain bearing winds also comes with the southwest monsoon from April to September,
though the rainfall during this period are generally less than during northeast monsoon [2]. There are
also two transitional period between the monsoon when convetional thunderstorm are common.
Floods usually occurred from November to January as the northeast monsoon brings large volume
of runoff to the relatively large catchment areas [3]. Major floods recorded in the study area;
especially at lower reach of the catchment are the flood of Dec 2003, Dec 2004, Dec 2005, Feb 2006
and Nov 2009[4]. High rainfall intensity and the properties of the river regime are among the factor of
Dungun flood [3]. It will be worsening as the rain occurs during the high tide to the low-lying area e.g.
Taman Rakyat, Dungun[5].

2. Study Area
Dungun River is the main river in Dungun district which comprises a catchment area of 1858 km$^2$ and river length of approximately 110 km, flowing through four mukims from Pasir Raja and flowing to Kuala Jengai, Jerangau and finally to Kuala Dungun (Figure 1). The Dungun River is the second largest river in Terengganu ranging from 50 meters to 300 meters in width [6]. Figure 2 shows the water level at Jambatan Jerangau during the 12$^{th}$ December 2004 flood event.

3. Methodology

International Centre for Water Hazard and Risk Management (ICHARM) under the auspices of UNESCO has developed a brief flood-runoff analysis system as a toolkit for more effective and efficient flood analysis in developing countries. This system is called Integrated Flood Analysis System (IFAS).

The application of IFAS which includes interface for utilisation of satellite-based rainfall as the input is suitable for the catchment in developing country which the availability of ground rainfall stations is limited. The design concept in developing the flood analysis model are [7] the software can utilize both satellite and ground-based rainfall as an input; implementation of runoff analysis engine; implementation of a model creation and a parameter estimation function; visualisation of flood result and free distribution.

3.1. Model Setting

Digital Elevation Model (DEM) and the landuse data are determined from the Global Data. Global data sets relevant to flood analysis which can be used create run-off analysis model and estimates parameters for the river basin. The elevation within the catchment area (Figure 3) can be determined and the model will then generate the catchment boundary.

3.2. Rainfall Input

Two types of rainfall data are used as input data to the IFAS model which are ground and satellite-based rainfall data. There are altogether six ground rainfall stations in the catchment area with four stations equipped with telemetry devices as listed in Table 1.

GSMaP (Global Satellite Mapping of Precipitation) is the name of the satellite rainfall data which uses the Microwave radiation device equipped with satellite TRMM/TMI, Aqua/AMSR-E, ADEOS-II/AMSR and DMSP/SSMI to provide hourly rainfall data to the catchment located within 60 degrees north and 60 degrees south longitude. GSMaP rainfall data can be automatically downloaded to IFAS by using the downloading function of rainfall data manager [8]. Table 2 lists the type of GSMaP data and the data availability.
3.3 Catchment Parameter

Three types of catchment parameter data from Global Map used in calibrating process which are surface, groundwater and river course parameter. The calculated discharge produced by IFAS is compared to the observed discharge data from river station at Jambatan Jerangau. Figure 4 shows the simulated hydrograph before and after calibration compared with the observed data.

![Figure 4. Simulated Hydrograph Before and After Calibration](image)

3.4 Result

The simulated hydrograph from both satellite and ground-based rainfall are compared with the observed hydrograph during flood event in 2003 as shown in Figure 5.

![Figure 5. Comparison Between Simulated and Observed Discharge during 2003 Flood Event](image)

3.5 Error Analysis

The calculated discharges are compared with the observed discharge and the calculated errors are shown in Table 3. Three types of error analysis are adopted in comparing the simulated and observed hydrograph.

a) The coefficient of efficiency [9] is define as:

\[ E_c = 1 - \frac{\sum_{i=1}^{n} (Q_{rec} - Q_{sim})}{\sum_{i=1}^{n} (Q_{rec} - \bar{Q}_{rec})} \]  

(1)

where \( Q_{rec} (t) \) is the recorded discharge at time \( t \), \( Q_{sim} (t) \) is the simulated discharge at time \( t \), \( \bar{Q}_{rec} \) is the average recorded discharge during the storm event, and \( n \) is the number of discharge records during the storm event. The better the fit, the closer \( CE \) is to unity.

b) The error of peak discharge [9] is define as:

\[ E_{p} = \frac{(Q_{p,rec} - Q_{p,sim})}{(Q_{p,rec} - \bar{Q}_{p,rec})} \]  

where \( (Q_{p})_{sim} \) is the peak discharge of the simulated hydrograph, and \( (Q_{p})_{rec} \) is the recorded peak discharge.

### Table 1. Ground-based Rainfall

| Station Name     | Station No | Data Transmission |
|------------------|------------|-------------------|
| Pasir Raja       | 4529001    | Telemetry         |
| Kuala Jengai     | 4730002    | Telemetry         |
| SM Sultan Omar   | 4734079    | Telemetry         |
| Jambatan Jerangau| 4832011    | Telemetry         |
| Delong           | 4833078    | Manual            |
| Kuala Abang      | 4834001    | Manual            |

### Table 2. Type of GSMaP

| Satellite-Based Rainfall | Data Period  |
|--------------------------|--------------|
| GSMaP MVK+               | January 2003  |
|                          | December 2006 |
| GSMaP NRT                | December 2006  |
|                          | Present       |
The error of the time to peak discharge \[9\] is defined as:

\[
E_p = \left[ \frac{(Q_p)_{\text{sim}} - (Q_p)_{\text{rec}}}{Q_p_{\text{rec}}} \right] \times 100 \% \tag{2}
\]

c) The error of the time to peak discharge \[9\] is defined as:

\[
E_{T_p} = (T_{p,\text{sim}} - (T_{p})_{\text{rec}}) \tag{3}
\]

where \((T_{p})_{\text{sim}}\) is the simulated time to peak discharge, and \((T_{p})_{\text{rec}}\) is the recorded time to peak discharge.

### Table 3: Calculated Error Analysis

| Event | Type of Rainfall Data | Coefficient of Efficiency | Time to Peak Error (Hour) | Peak Discharge Error (%) |
|-------|-----------------------|---------------------------|---------------------------|--------------------------|
| 2003  | Ground                | 0.72                      | 9                         | 1.68                     |
|       | Satellite             | 0.36                      | 3                         | 41.96                    |

### 4. Conclusion

The simulated discharge produced by IFAS for all the events are compared to the observed discharge station at Jambatan Jerangau. IFAS software is able to mimic the shape of the observed hydrograph quite satisfactorily by using the concept of tank model. However, it is noticed that the satellite data provided by GSMAp does not truly represent the ground-based rainfall data at ground level as the satellite data always overestimated result of hydrograph compared to ground-based rainfall. This phenomenon is inherent as the satellite-based rainfall data obtained in the upper atmosphere which represent the overall catchment rainfall while the ground-based rainfall representing the point rainfall where the station located.

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