



Mekong River Commission Regional Flood Management and Mitigation Programme

Flood Forecasting Performance Evaluation Report 2012



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Flood Forecasting Performance Evaluation Report 2012

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1. Introduction

The MRC Mekong Flood Forecasting System is based on a) Deltares's Flood Early Warning System (Delft-FEWS or in short FEWS) as the flood modelling platform, b) the hydrological model Unified River Basin Simulation (URBS) as a trial model for flood forecasting decided by the Regional Consultation Meeting on 1st December 2006, and c) the hydraulic model ISIS (installed in the system after 2008 flood season) for the Cambodian Floodplain, Great Lake system and the Mekong Delta. The system had been tested during the 2009 flood season and is officially used for flood forecast operations from 2010 onward.

At present, MRC Mekong River Flood Forecasting System (FFS) uses Satellite Rainfall Estimation (SRE) and Numerical Weather Prediction (NWP) obtained from NOAA as the current and forecast-rainfall data input for its flood forecasting. The SRE is a grid based product of 24 hours derived from satellite estimates of cloud top temperatures and resemble yesterday rainfall over the basin. The SRE data is calibrated by NOAA to a limited number of ground truth observations obtained through the WMO's GTS. The number of observation stations varies from 5 to 35 stations on any particular day. The NWP provides 7-day GFS forecast rainfall with 0.3750 of spatial resolution (approximately 40km x 40km) and a 1 day temporal resolution.

As SRE tends to over and under-estimate rainfall in various location on the Lower Mekong Basin (LMB), Dr. W.W. Immerzeel (a senior international satellite precipitation expert) had developed a methodology/tool and implemented bias correction for SRE used by MRC Mekong Flood Forecasting System (MRCFFS) before 2010 flood season. The resulting bias correction SRE is also officially utilized together with SRE and NWP in MRC-FFS.

Another grid rainfall named Tropical Rainfall Measuring Mission (TRMM), which is a joint USA-Japan mission to monitor tropical and subtropical precipitation, is also recommended by the expert to be utilized as another source of backup rainfall input for the system.

This report is produced by the flood forecasting team for the evaluation of the 2012 forecast results of the system by two model combinations: URBS – Regression and URBS – ISIS with two input data sources of SRE and bias corrected SRE (C-SRE) through 2012 flood season. As TRMM is used as backup input data, the TRMM based forecast results will also be evaluated and compared with forecast results based on SRE.

2. Overview 2012 Flood Season

The 2012 flood season in the Lower Mekong Basin (LMB) was considered drier than the long term average (LTA), in contrast to last year that flood inundation extended from middle to lower reaches of LMB. The water levels along the Mekong River were similar to those of the year 1992 (which is the driest year in terms in the twenty comparable years on records in the period 1992-2012) as shown in Annex (Seasonal water level graphs).

The onset of the flood season took place by the end of May. Similar to the water levels in previous years, and like in the year 1992, water levels in the first two months (June and July) were below the long term average (LTA); then increased above those of the year 1992 and the LTA for the next two months (August and September); finally recessed to conform with the year 1992, but below the LTA. Exceptions include stations from the middle to the lower reaches (Nakhon Phanom to Chau Doc) where water levels fluctuated around LTA during the first two months (June and July); then followed under the LTA during the rest of flood season.

Table 2-1 shows the flood peaks of main locations along the Mekong mainstream during the 2012 flood season. Most water levels along the Mekong River mainstream were below the alarm level , except Nong Khai station, where the water level only raised once above the alarm level on 4 August, however did not reach the flood level during the rest of the flood season. See for more details the Seasonal Water Level Graphs in the Annex.

Table 2-1 Flood Peaks in the flood season 2012.

ID	Station	Alarm level	Flood Level	Day/Month of Peak	Hmax (m)	Comment
010501	Chiang Saen	11.50	11.80	29-Jul	7.91	Below alarm level
011201	Luang Prabang	17.50	18.00	23-Aug	15.25	Below alarm level
011903	Chiang Khan	17.32	17.40	02-Aug	13.28	Below alarm level
011901	Vientiane	11.50	12.50	25-Aug	10.28	Below alarm level
012001	Nong Khai	11.40	12.20	04-Aug	11.66	Above alarm level
012703	Paksane	13.50	14.50	12-Aug	12.42	Below alarm level
013101	Nakhon Phanom	12.60	12.70	13-Aug	10.22	Below alarm level
013102	Thakhek	13.00	14.00	13-Aug	11.31	Below alarm level
013402	Mukdahan	12.50	12.60	13-Aug	9.99	Below alarm level
013401	Savanakhet	12.00	13.00	13-Aug	8.85	Below alarm level
013801	Khong Chiam	16.00	16.20	04-Sep	11.17	Below alarm level
013901	Pakse	11.00	12.00	04-Sep	9.4	Below alarm level
014501	Stung Treng	10.70	12.00	05-Sep	9	Below alarm level
014901	Kratie	22.00	23.00	06-Sep	19.55	Below alarm level
019803	Kompong Cham	15.20	16.20	07-Sep	13.46	Below alarm level
020101	Phnom Penh Port	9.50	11.00	29-Sep	7.7	Below alarm level
033401	Phnom Penh Bassac	10.50	12.00	29-Sep	8.56	Below alarm level
033402	Koh Khel	7.40	7.90	17-Sep	6.94	Below alarm level
019806	Neak Luong	7.50	8.00	01-Oct	6.12	Below alarm level
020102	Prek Dam	9.50	10.00	01-Oct	7.76	Below alarm level
019803	Tan Chau	3.50	4.50	13-Oct	3.19	Below alarm level
039801	Chau Doc	3.00	4.00	13-Oct	2.86	Below alarm level

(Alarm level, flood level are defined by the national line agency)

The Lower Mekong Basin is influenced by typhoons, tropical storms and the Inter Tropical Converge Zone (ITCZ) as usual. During the flood season 01 June to 15 October 2012, there were 6 tropical storms and typhoons which affected the Basin: TALIM (1205), DOKSURI (1206), KAI-TAK (1207), TEMBIN (1214), BOVALEN (1215) and GAEMI (1220). During flood season 2012 there were roughly seven ICZM periods that caused heavy rain in the area. Details of these influences are as follows:

Periods affected by tropical storm and typhoon:

- TALIM (1205) : 18-24 June 2012;
- DOKSURI (1206) : 27 June-02 July 2012;
- KAI-TAK (1207) : 13-19 August 2012;
- TEMBIN(1214) and BOVALEN (1215) : 21-27 August 2012, and
- GAEMI (1220) : 04-06 October 2012.

Periods affected by inter tropical converge zone (ITCZ):

- 04-10 June 2012;
- 16-18 June 2012;
- 03-09 July 2012;
- 30 July- 05 August 2012,
- 06 - 12 August 2012;
- 27 August-30 September 2012, and
- 07-15 October 2012.

Rainfall distribution over the LMB of the period of 5 consecutive months during the 2012 flood season is presented in Figure 2-1. This reveals that most heavy rainfall happened in the middle reach of LMB (in the area between Paksane and Pakse) similar to last year. There was not much rainfall during the flood season 2012, as compare to 2011. See Table 2-2 for details.

One can distinguish three reaches in the Lower Mekong Basin: the Upper Reach from Chiang Sean to Nong Khai, the Middle Reach from Paksane to Pakse, and the Lower Reach from Strung Treng to Chau Doc. The accumulative average rainfall distributions for each of these reaches during the period 01 June–15 October of the years 2011 and 2012 are shown in Figure 2-2, Figure 2-3, and Figure 2-4, which reveal that:

1. In the Upper Reach (see Figure 2-2), rainfall patterns in the June of both years were different due to the fact that typhoon Haima in 2011 brought more rain around end of the month, while typhoon Doksuri in 2012 came a week later, resulting in accumulative rainfall of 255 mm in 2011 and 171 mm in 2012. Then rainfall increased at an almost constant rate until the end of July with 604 mm in 2011 and 407 mm in 2012. Right at the beginning of August 2011, typhoon Nok Ten increased rainfall by more than 100 mm in the upper reach, while typhoon Kai Tak in 2012 less affected the area, and only the water level at the Nong Khai gauging station reached the alarm level in 2012. Rainfall increased almost at a constant rate until mid of September for both years, however the inter tropical converge zone (ITCZ) in 2011 brought more rain (around 400 mm) as compare to 2012. By the end of the year the total accumulative depth of rainfall was 1,413 mm in 2011 and 839 mm in 2012. See for details Table 2-2.
2. For the Middle Reach (see Figure 2-3), rainfall patterns in June were similar for both years as a result of typhoon Haima in 2011 and typhoon Doksuri in 2012 (compared to 2011, Doksuri happened one week later). This had similar affects on the middle reach of LMB and accumulative rainfall by the first week of July had increased up to 480 mm in both 2011 and 2012. Right at the beginning of August 2011, typhoon Nok Ten had increased the rainfall by more than 700 mm in the Middle Reach. The three typhoons Kai Tak in 2012 (which happened one week later than Nok Ten in 2011), Tembin and Bovalendoes had all less affected the area. The accumulative rainfall had increased by the end of August to 1,484 mm in 2011 and 962 mm in 2012. Then, the inter tropical converge zone (ITCZ) in 2011 brought more rain (around 450 millimetres) as compared to 2012 and the accumulative rainfall increased until the end of the flood season to about 2,076 mm in 2011 and merely 1,220 mm in 2012.

- For the Lower Reach (Figure 2-4), rainfall patterns in June 2011 and 2012 were different. The accumulative rainfall by the end of June was 169 mm in 2011 and 86 mm in 2012. In 2011 the rainfall increased at a constant rate, while almost no rain fell in 2012. In 2011 typhoon Haima in 2011 and typhoon Doksuri in 2012 (which happened a week later) had less affects on the lower reach of LMB. Effects of typhoons were less in the lower reach of LMB for both years and the accumulative rainfall was 984 mm by the end of October in 2011 and 875 mm in 2012.

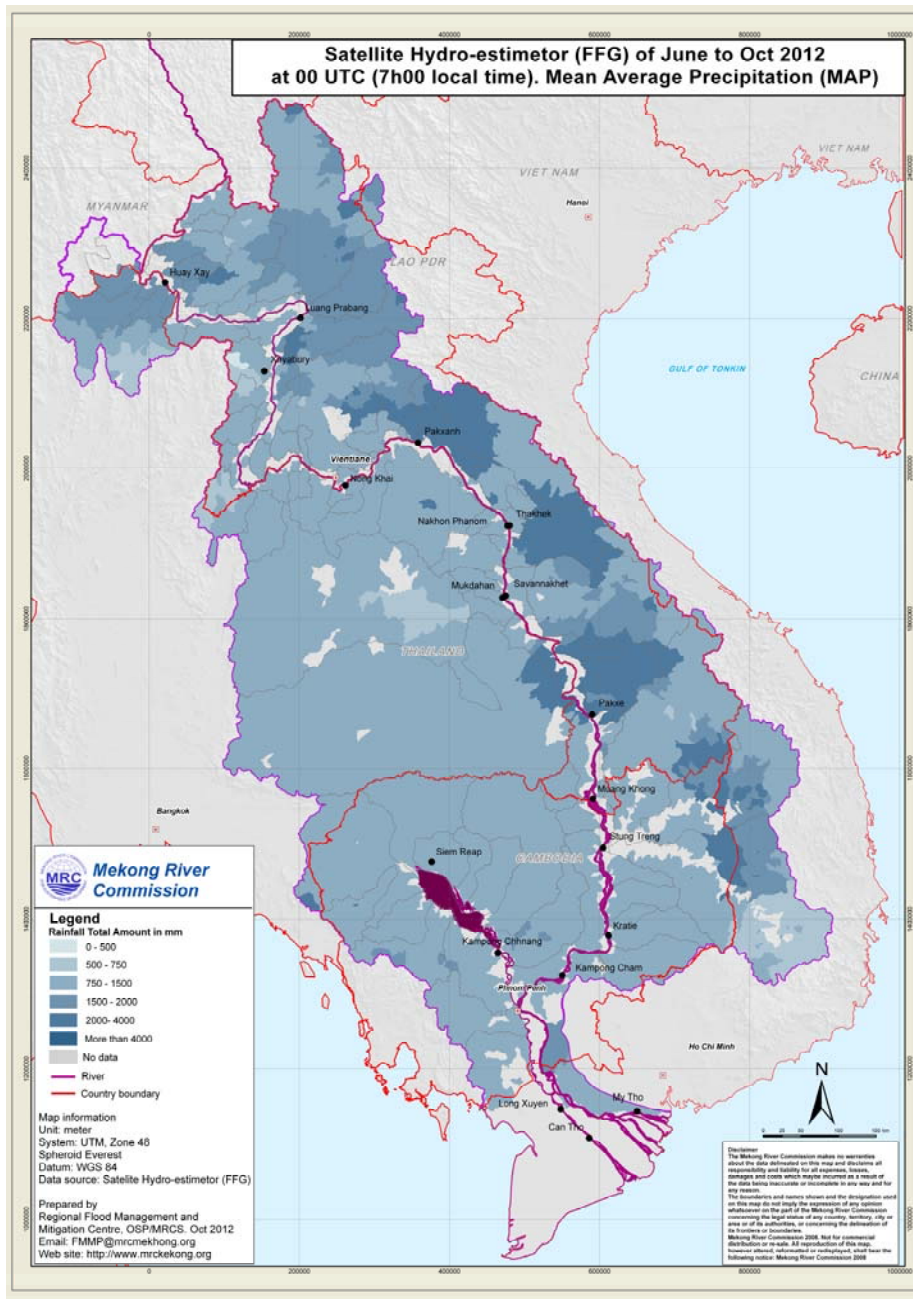


Figure 2-1 Distribution of the amount of rainfall over the LMB covering a 5 months period of the flood season 2012.

Table 2-2 Accumulative average rainfall for Upper, Middle and Lower Reaches of LMB at the end of month in the year 2011 and 2012

	Accumulative rainfall at the end of month (millimetres)					
	Upper Reach		Middle Reach		Lower Reach	
	2011	2012	2011	2012	2011	2012
June	255	171	355	248	169	86
July	604	407	901	622	353	343
August	996	590	1,484	962	607	471
September	1,328	761	1,956	1,193	860	746
October	1,413	839	2,076	1,220	984	875

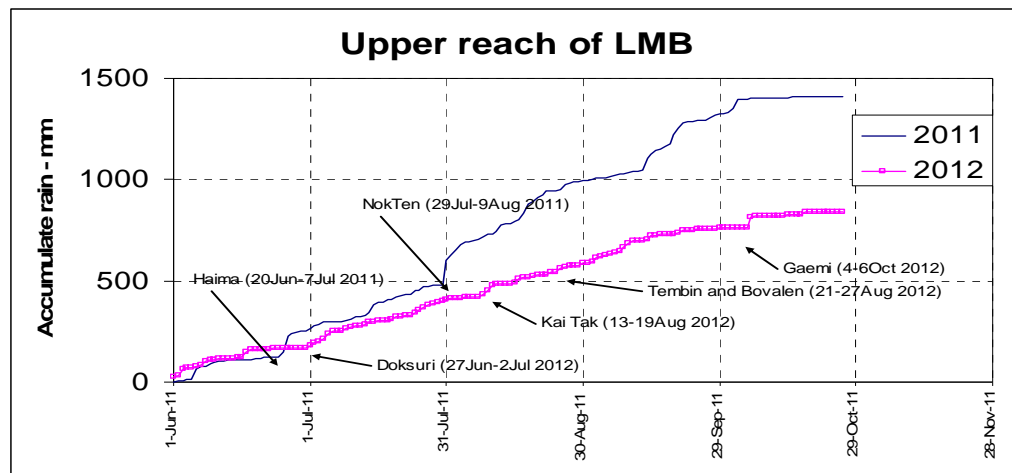


Figure 2-2 Accumulated Rainfall over the Upper Reach of LMB covering 5 months of the flood season 2012.

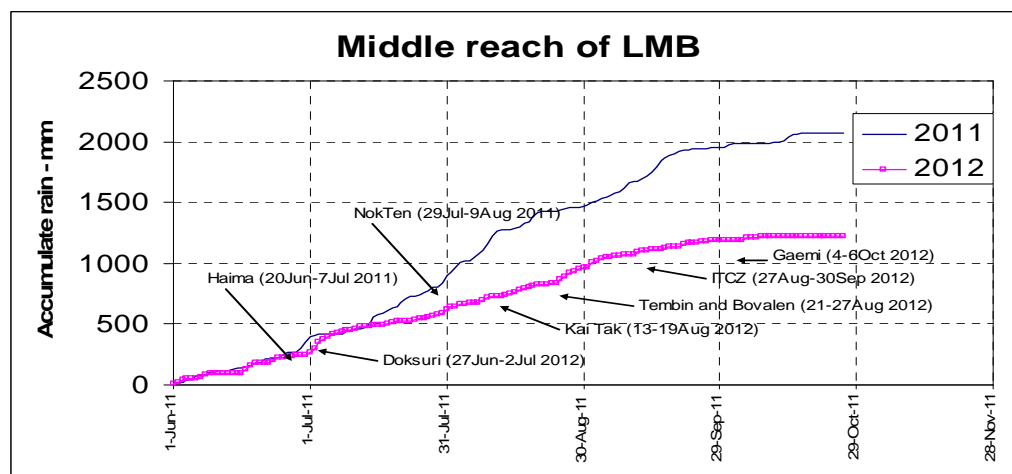


Figure 2-3 Accumulated Rainfall over the Middle Reach of LMB covering 5 months of the flood season 2012.

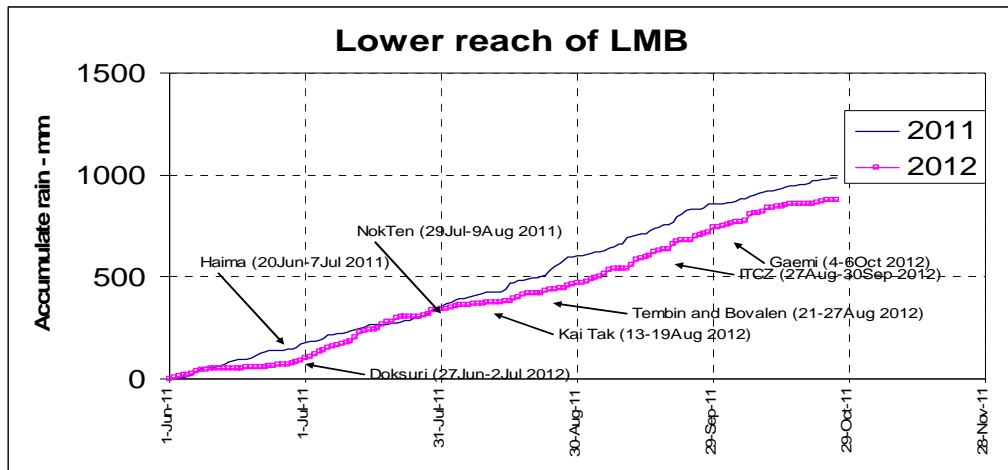


Figure 2-4 Accumulated Rainfall over the Lower Reach of LMB covering 5 months of the flood season 2012.

3. System Performance Evaluation of Forecasting Accuracies for the Flood Season 2012

3.1 General situation of the MRC Flood Forecasting System (MRCFFS)

Flood forecast lead times in the Lower Mekong Basin are defined as follow:

- Short term 1-5 days
- Medium term 6-10 days
- Long term >30 days

During flood period (01 June–31 October), the MRC flood forecast system is carried out daily and issues flood bulletin based on short term forecasting for 22 locations along the main stream. The forecast results if only based on observed water levels at upstream stations (known as “flood routing”) can provide accurate forecast if there is not much rainfall over the catchments/tributaries during forecast time. However the forecast lead time is limited to in-stream travel-time between each station (1 - 5 days, depending on location along main stream). Therefore, in general situation with rainfall happens inside basins, the forecast accuracies (arrival time and water level) are largely dependant on the rainfall falls in the upstream catchments and tributaries. Heavy rainfall may cause sudden rises of the water levels; therefore, for better accuracies of flood forecasting with longer lead times, both observed and forecasted rainfall are required.

At present, the MRCFFS employs both manually recorded historic data (water level and rainfall) collected from ground truth stations and two different data sources of satellite rainfall: SRE and bias corrected SRE. These datasets are utilized for simulating the current situation and then employs forecast grid rainfall obtained from Numerical Weather Prediction model of NOAA (GFAS) to project basin flood behaviours to next few days in the future.

The MRCFFS provides forecast results from Chiang Saen in the Upper Reach to Pakse in the Middle Reach of LMB by using the hydrological model URBS; from Strung Treng downstream to Tan Chau/ Chau Doc in the Lower Reach of LMB by using the hydraulic model ISIS and Regression. Four forecast results: ISIS-SRE, REG-SRE, ISIS-C-SRE and REG-C-SRE are provided to the flood forecaster-in-charge as per daily operational forecast practices.

3.2 Input data

The Mekong FFS is based on URBS (hydrologic model) which use observed and forecast rainfall and observed water levels as the primary input. At the current time, the system uses historical satellite rainfall SRE and forecast grid rainfall (GFAS); and observed rainfall from ground truth stations. Manual water levels observations are primary sourced of water level utilized by URBS while there is an increasing trend to use telemetry data from the MRC Hydromet Network (AHNIP and HYCOS stations) to substitute manual data in the future.

Bias Corrected SRE (C-SRE; obtained by applying bias factors derived from ground observation rainfalls to SRE) was developed by an international satellite precipitation expert aiming at improving the rainfall estimated over the basin. It is also another source of rainfall input to URBS model. It has been officially incorporated and is applied in forecasting operation since flood season 2011.

Besides this, another option for operational SRE is the product provided by the Tropical Rainfall Monitoring Mission (TRMM). Combining visible, infrared, passive microwave and radar is most likely the best spectral satellite-based rainfall monitoring system. TRMM consists of a closely knit combination of (i) a passive microwave radiometer TRMM Microwave Imager (TMI), (ii) a precipitation Radar (PR) and (iii) A visible/infrared (VIS/TIR) radiometer. More details on the TRMM sensor specification can be found in Kummerow et al. (1998). At this moment, TRMM is used as a backup rainfall input to the MRCFFS.

3.3 Performance evaluation of forecasting accuracy with difference of input data sources

3.3.1 Flood forecasting accuracy by using two official input data sources SRE and bias corrected SRE (C-SRE)

Since 2008, the MRCFFS has utilized the URBS model for locations in the Upper and Middle reaches of LMB between Chiang Saen (Thailand) and Pakse (Lao PDR) while applied the hydrodynamic model ISIS and Regression model for locations in downstream between Strung Treng (Cambodia) and Tan Chau/Chau Doc (Viet Nam). Therefore, evaluation of flood forecasting accuracy for flood season 2012 will be based on comparison between forecast results made by URBS - ISIS and URBS - Regression with two satellite rainfall data sources: SRE and Bias Corrected SRE (C-SRE) as input.

The Mean Absolute Error (MAE) has been adopted as the major measure of forecasting performance since it is a reliable indicator of error magnitudes and it is a robust measure. Figure 3-1 and Figure 3-2 show performances of forecast results by URBS - ISIS, URBS - Regression, when using SRE and bias corrected SRE as rainfall data sources. In order to achieve the forecasting goal, a Benchmarks of Success for 1 to 5 day forecast lead time (Indicator of accuracy is mean absolute error in centimeters) shown in Table 3-1 is utilized for comparison.

The graphs of MAE in Figure 3-1 and Figure 3-2 for the 2012 flood season show the normal pattern in which accuracies are improved from stations in the Upper to Lower Reach of the LMB. Exceptions are noticed for Vientiane, Nongkhai, Paksane, Khong Chiam, Kratie and Kompong Cham, where accuracies are worse for 3-day to 5-day forecast lead time.

The comparison of the forecast accuracy for 1-day to 5-day lead time at 22 main stations along the Mekong River mainstream during the 2012 flood season is presented in Figure 3-3. This information reveals that forecast results generated by URBS - Regression were more accurate than the forecasts generated by URBS - ISIS. This is especially valid at downstream stations from Strung Treng to Tan Chau/Chau Doc for 1-day to 5-day forecast lead times. The daily forecast achievement also confirms that results made by URBS -

Regression were better than the forecasts made by URBS – ISIS for both SRE and C-SRE inputs. See Table 3-2 to Table 3-5,

The assessment made for the 2012 forecasts is based on the benchmarks of success (Table 3-1) and the achievements of forecast results by URBS - ISIS (presented in Table 3-2 and Table 3-4); and by URBS - Regression (in Table 3-3 and Table 3-5) using SRE and C-SRE rainfall inputs respectively. It can be seen that the achieved percentiles of forecasts by URBS - Regression are much higher than that of forecasts by URBS - ISIS at most locations especially at downstream stations from Strung Treng to Tan Chau/Chau Doc for almost all forecast lead times. Results for the 5-day forecast are quite similar.

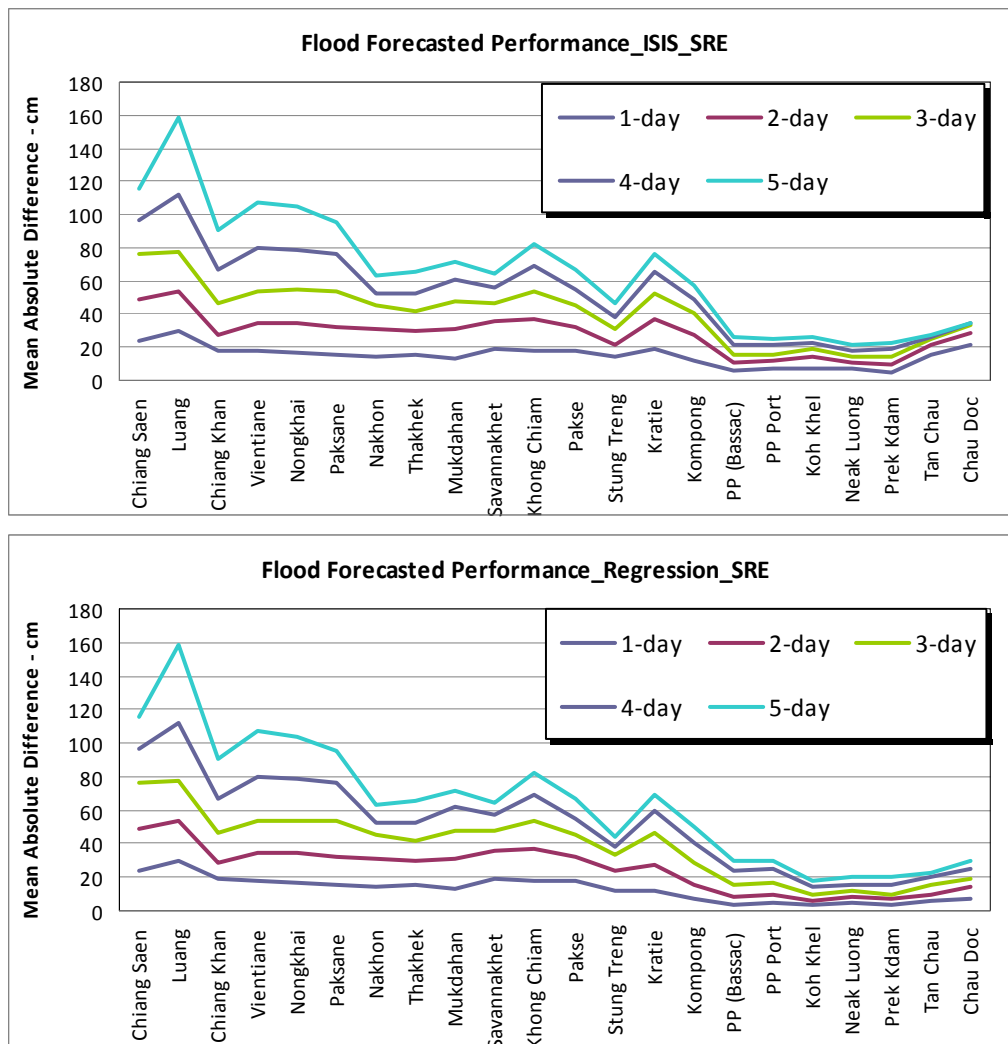


Figure 3-1 Forecast performance based on original result by URBS-ISIS and URBS-Regression using SRE for the flood season 2012.

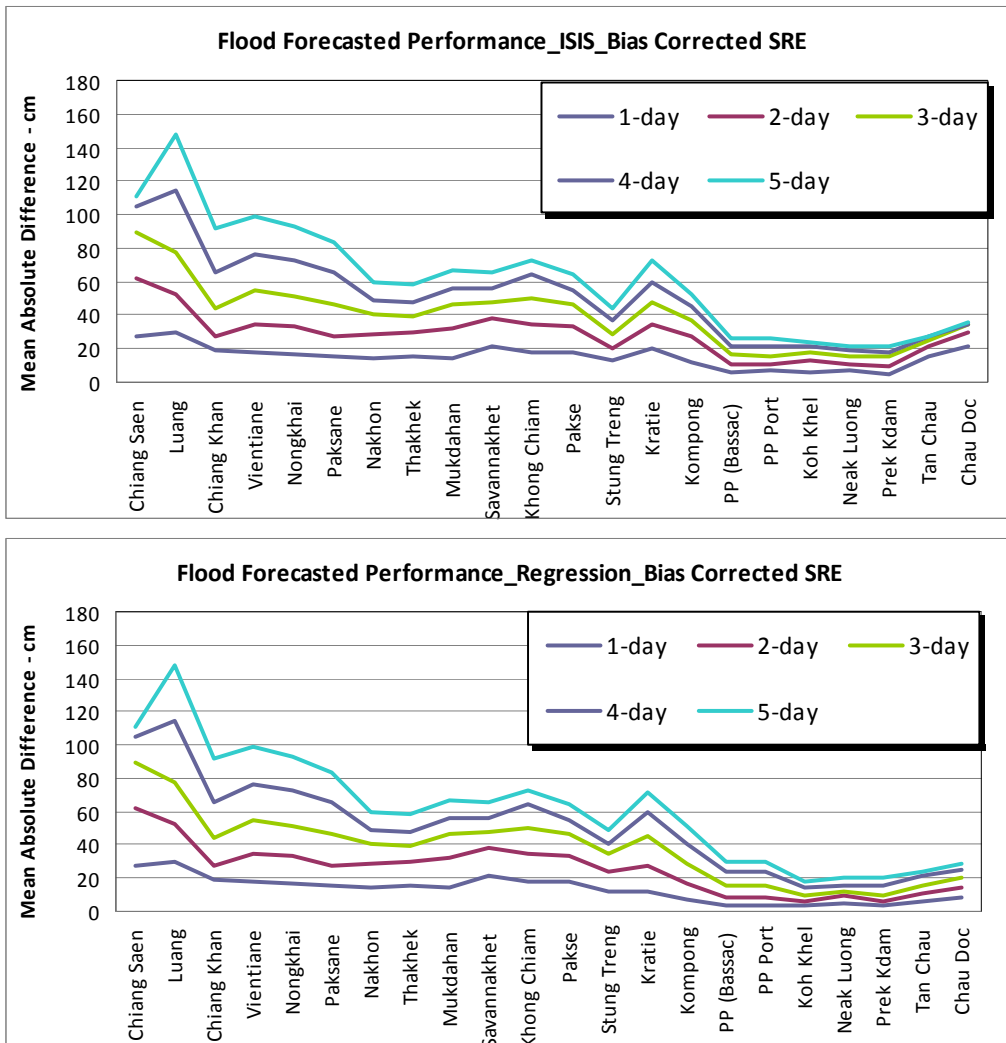


Figure 3-2 Forecast performance based on original result by URBS-ISIS and URBS-Regression using Bias Corrected SRE for flood season 2012.

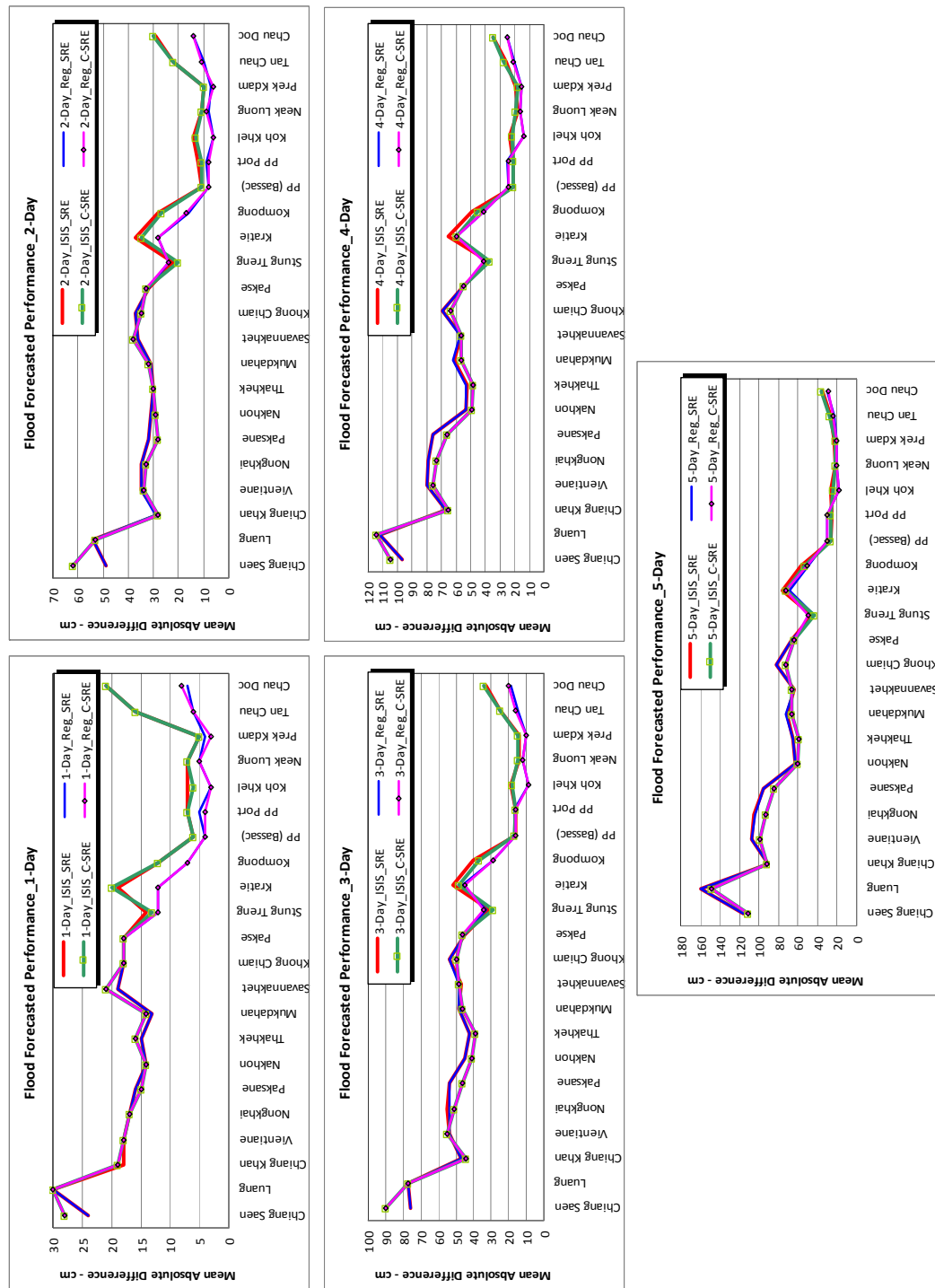


Figure 3-3 Forecast accuracy for 1-day to 5-day lead time at 22 main stations in the LMB during the flood season 2012; comparison between ISIS and Regression using 2 data sources: SRE and Corrected SRE (C-SRE).

Table 3-2 Achievement of daily forecast results against benchmarks (%), based on ISIS-SRE.

	Chiang Saen	67.2	65.0	46.0	51.1	30.1
	Luang Prabang	62.0	57.7	37.2	37.2	21.3
	Chiang Khan	70.8	83.2	63.5	44.5	33.1
	Vientiane	40.1	48.9	31.4	38.0	28.7
	Nongkhai	44.5	47.4	28.5	35.8	24.3
	Paksane	48.2	51.8	25.5	36.5	22.1
	Nakhon Phanom	57.7	55.5	38.7	58.4	51.5
	Thakhek	45.3	54.7	35.0	60.6	47.1
	Mukdahan	57.7	59.1	41.6	54.7	43.4
	Savannahet	43.1	47.4	33.6	53.3	50.0
	Khong Chiam	43.1	48.2	29.2	47.4	36.0
	Pakse	43.1	55.5	41.6	54.7	41.2
	Stung Treng	46.7	67.9	54.0	73.0	66.2
	Kratie	32.8	41.6	29.9	46.7	40.4
	Kompong Cham	64.4	58.5	38.5	64.4	54.5
	PP (Bassac)	88.1	65.9	49.6	36.3	61.2
	PP Port	80.7	60.7	45.2	68.1	58.2
	Koh Khel	85.9	53.3	44.4	35.6	64.2
	Neak Luong	76.3	67.4	54.8	74.8	70.1
	Prek Kdam	88.9	66.7	52.6	73.3	67.2
	Tan Chau	57.0	43.0	33.3	33.3	56.7
	Chau Doc	43.7	30.4	21.5	20.0	46.3
	Average	58.5	55.9	39.8	49.9	46.1
1-day						
2-day						
3-day						
4-day						
5-day						

Table 3-3 Achievement of daily forecast results against benchmarks (%), based on Regression-SRE.

	Chiang Saen	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Kheh	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average
1-day	67.2	70.8	40.1	44.5	48.2	57.7	45.3	57.7	42.3	42.3	43.1	59.9	61.3	88.1	91.9	91.1	96.3	87.4	96.3	83.7	80.7	66.3
2-day	65.0	82.5	48.9	47.4	51.8	54.7	54.0	59.1	47.4	48.2	55.5	67.9	61.3	85.9	80.0	78.5	85.9	74.1	85.9	67.4	60.0	64.5
3-day	46.0	63.5	32.1	28.5	25.5	38.0	35.0	41.6	33.6	29.2	41.6	48.9	40.9	60.0	46.7	45.2	75.6	64.4	67.4	46.7	45.2	45.1
4-day	51.1	44.5	38.7	36.5	36.5	58.4	60.6	54.7	53.3	47.4	54.7	71.5	58.4	71.9	29.6	68.1	58.5	81.5	88.1	35.6	28.9	53.0
5-day	30.1	33.1	29.4	25.0	22.1	51.5	47.1	43.4	49.3	36.0	41.2	66.2	52.2	62.7	54.5	53.0	82.8	75.4	79.9	67.9	60.4	49.3

Table 3-4 Achievement of daily forecast results against benchmarks (%), based on ISIS-bias corrected SRE.

	1-day	55.5	65.0	70.8	70.8	46.0	48.2	53.3	51.1	47.4	51.8	45.3	46.0	43.8	53.3	35.0	61.5	85.9	83.0	87.4	72.6	88.1	55.6	40.7	58.5	
Chang Saen	2-day	46.7	65.7	82.5	56.2	54.7	59.9	59.9	59.9	57.7	56.9	54.7	49.6	47.4	73.0	43.1	60.7	65.2	65.9	60.7	60.7	65.2	67.4	40.7	28.9	57.3
Luang Prabang	3-day	32.1	42.3	69.3	37.2	41.6	41.6	41.6	41.6	43.1	38.7	40.9	43.1	43.1	54.0	30.7	45.9	46.7	43.0	47.4	47.4	58.5	51.9	33.3	24.4	42.7
Chiang Khan	4-day	39.4	40.1	51.8	45.3	48.9	63.5	63.5	70.1	70.1	56.2	53.3	54.0	61.3	75.9	48.2	62.2	29.6	70.4	41.5	41.5	74.1	75.6	31.1	17.8	52.5
Chiang Saen	5-day	34.6	29.4	33.1	35.3	39.0	52.2	52.2	53.7	53.7	47.1	49.3	46.3	52.2	70.6	44.1	62.7	57.5	55.2	64.9	64.9	69.4	70.9	56.0	44.0	49.9
Chang Saen	Average																									

Table 3-5 Achievement of daily forecast results against benchmarks (%), based on Regression-bias corrected SRE.

1-day	Chiang Saen	55.5	65.0	70.8	46.0	48.2	53.3	51.1	47.4	51.8	45.3	46.0	43.8	59.9	62.8	89.3	93.9	93.9	95.4	87.8	97.7	85.5	80.9	66.9
2-day	Chiang Saen	46.7	65.7	82.5	52.6	56.2	59.9	59.9	57.7	56.9	54.7	49.6	47.4	67.9	60.6	86.4	80.3	79.5	87.1	73.5	85.6	67.4	60.6	65.4
3-day	Chiang Saen	32.1	42.3	69.3	32.8	37.2	41.6	41.6	43.1	38.7	40.9	43.1	41.6	51.8	40.9	62.1	45.5	46.2	73.5	63.6	66.7	47.0	43.9	47.5
4-day	Chiang Saen	39.4	40.1	51.8	43.8	45.3	48.9	63.5	70.1	56.2	53.3	54.0	61.3	70.1	56.2	70.0	28.5	70.0	60.0	80.8	89.2	34.6	29.2	55.3
5-day	Chiang Saen	34.6	29.4	33.1	29.4	35.3	39.0	52.2	53.7	47.1	49.3	46.3	52.2	63.2	47.8	62.5	54.4	56.6	82.4	75.7	79.4	67.6	63.2	52.5
	Average																							
	Chiang Saen																							
	Luang Prabang																							
	Chiang Khan																							
	Vientiane																							
	Nongkhai																							
	Paksane																							
	Nakhon Phanom																							
	Thakhek																							
	Mukdahan																							
	Savannahet																							
	Khong Chiam																							
	Pakse																							
	Stung Treng																							
	Kratie																							
	Kompong Cham																							
	PP (Bassac)																							
	PP Port																							
	Koh Kheh																							
	Neak Luong																							
	Prek Kdam																							
	Tan Chau																							
	Chau Doc																							
	Average																							

In the MRCFFS the forecasts at stations in lower part of LMB are based on the results from ISIS and Regression, while the forecast results at stations in upper and middle parts are provided by URBS model. With these results of the year 2012, the same conclusion made in 2011 is confirmed, namely that the hydrodynamic model ISIS in the system needs to be improved, because of unreliable forecast results for 1-day to 4-day forecast lead times. For 5-day forecast, one may use the results by both models ISIS and Regression.

During the 2012 flood season the LMB was influenced by six typhoons/tropical storms as mention in section 2 and these affected the LMB in different ways. Of these, two tropical storms namely KAI-TAK and GAEMI were the most noticeable and will be elaborated more.

Figure 3-4, Figure 3-5, and Figure 3-6 present forecast performances, based on results of the system when KAI-TAK and GAEMI storms influenced to the LMB and the period of critical ITCZ appearances during mid-September. The achievements in percentiles are shown in Table 3-6 to Table 3-11 respectively.

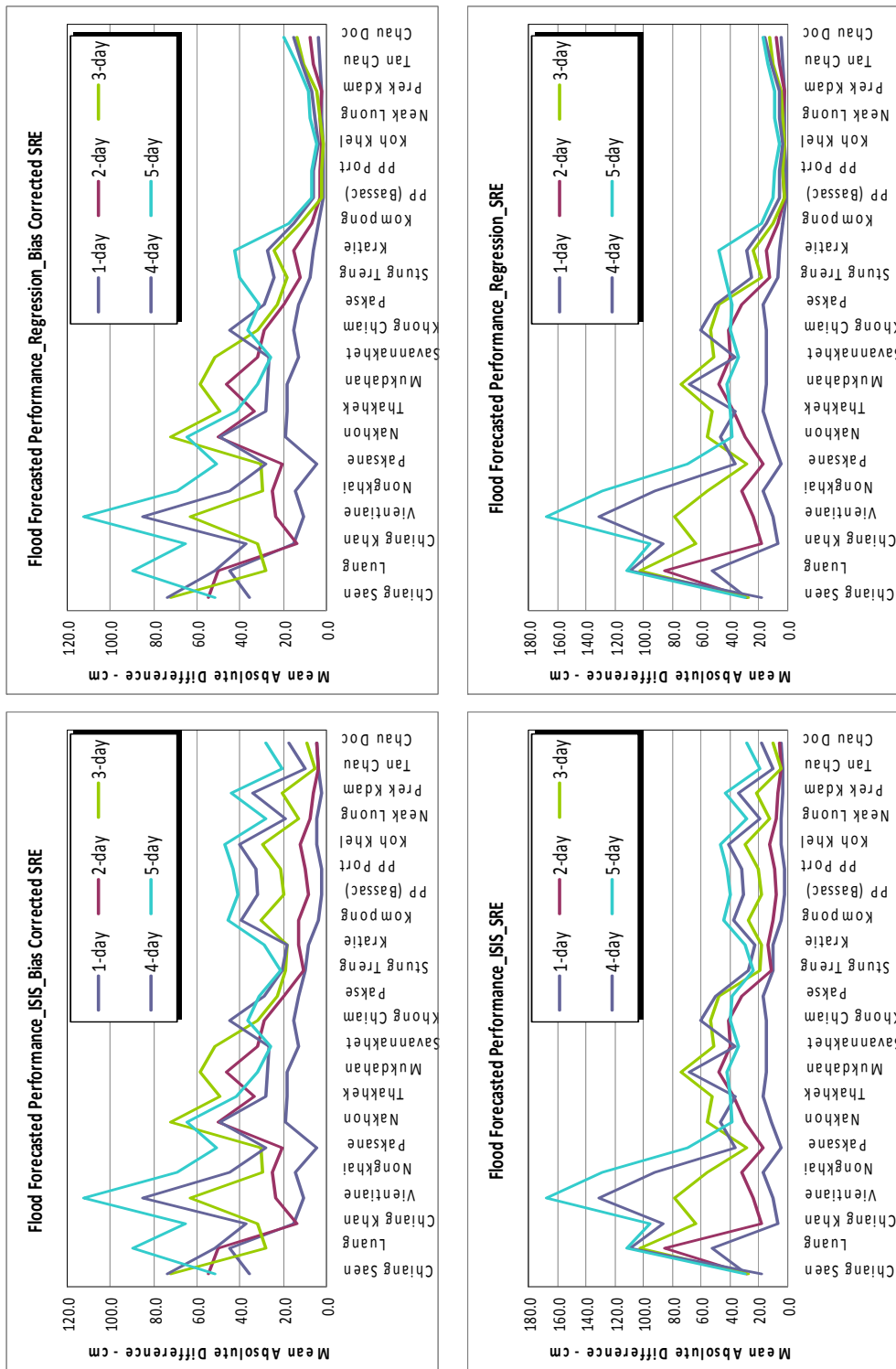


Figure 3-4 Forecast performance based on original result by URBS-ISIS and URBS-Regression using SRE and corrected SRE when KAI-TAK storm influenced to the LMB (13–19 August 2012).

Table 3-6 Achievement of daily forecast results against benchmarks (%) for URBS-ISIS and URBS-Regression using corrected SRE during KAI-TAK storm appearance (13–19 August 2012).

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannahet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khei	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average	
1-day	28.6	42.9	71.4	71.4	42.9	100.0	0.0	28.6	0.0	57.1	42.9	57.1	71.4	71.4	100.0	71.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	67.5
2-day	42.9	57.1	100.0	28.6	57.1	71.4	14.3	28.6	28.6	42.9	71.4	85.7	85.7	85.7	100.0	71.4	57.1	42.9	71.4	85.7	100.0	100.0	100.0	64.9
3-day	28.6	100.0	85.7	14.3	42.9	42.9	0.0	28.6	14.3	28.6	42.9	57.1	71.4	85.7	57.1	57.1	42.9	28.6	57.1	42.9	85.7	71.4	71.4	48.7
4-day	57.1	71.4	71.4	28.6	71.4	71.4	57.1	100.0	71.4	71.4	71.4	71.4	85.7	85.7	57.1	28.6	28.6	14.3	71.4	28.6	71.4	71.4	28.6	59.7
5-day	71.4	42.9	57.1	14.3	71.4	85.7	28.6	71.4	71.4	100.0	85.7	85.7	100.0	100.0	71.4	14.3	14.3	14.3	57.1	14.3	71.4	71.4	57.1	59.1
	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannahet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khei	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average	
1-day	28.6	42.9	71.4	71.4	42.9	100.0	0.0	28.6	0.0	57.1	42.9	57.1	71.4	71.4	100.0	71.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	66.9
2-day	42.9	57.1	100.0	28.6	57.1	71.4	14.3	28.6	28.6	42.9	71.4	85.7	100.0	71.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	70.1
3-day	28.6	100.0	85.7	14.3	42.9	42.9	0.0	28.6	14.3	28.6	42.9	57.1	85.7	57.1	100.0	100.0	100.0	100.0	100.0	100.0	57.1	42.9	60.4	
4-day	57.1	71.4	71.4	28.6	71.4	71.4	57.1	100.0	71.4	71.4	71.4	71.4	100.0	85.7	100.0	83.3	100.0	83.3	100.0	100.0	66.7	33.3	75.8	
5-day	71.4	42.9	57.1	14.3	71.4	85.7	28.6	71.4	71.4	100.0	85.7	85.7	71.4	57.1	100.0	100.0	100.0	100.0	100.0	100.0	85.7	85.7	76.6	

Table 3-7 Achievement of daily forecast results against benchmarks (%) for URBS-ISIS and URBS-Regression using SRE during KAI-TAK storm appearance (13–19 August 2012).

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average	
1-day	42.9	14.3	100.0	57.1	28.6	85.7	57.1	28.6	42.9	28.6	57.1	42.9	42.9	42.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	66.9
2-day	100.0	28.6	100.0	42.9	14.3	85.7	42.9	28.6	57.1	42.9	42.9	57.1	100.0	85.7	100.0	71.4	71.4	42.9	71.4	71.4	100.0	100.0	100.0	66.2
3-day	85.7	14.3	28.6	0.0	0.0	42.9	14.3	0.0	28.6	14.3	28.6	14.3	57.1	71.4	71.4	42.9	42.9	28.6	57.1	42.9	85.7	71.4	28.6	37.7
4-day	100.0	28.6	0.0	0.0	14.3	71.4	42.9	85.7	57.1	57.1	42.9	42.9	85.7	100.0	71.4	28.6	42.9	14.3	71.4	28.6	71.4	28.6	49.4	
5-day	100.0	42.9	14.3	0.0	0.0	14.3	71.4	85.7	85.7	100.0	71.4	71.4	85.7	85.7	71.4	28.6	14.3	14.3	57.1	14.3	71.4	57.1	52.6	
	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average	
1-day	42.9	14.3	100.0	57.1	28.6	85.7	57.1	28.6	42.9	28.6	57.1	42.9	42.9	42.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	68.8
2-day	100.0	28.6	100.0	42.9	14.3	85.7	42.9	28.6	57.1	42.9	42.9	57.1	100.0	71.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	70.8
3-day	85.7	14.3	28.6	0.0	0.0	42.9	14.3	0.0	28.6	14.3	28.6	14.3	85.7	57.1	100.0	100.0	100.0	100.0	100.0	100.0	57.1	42.9	50.6	
4-day	100.0	28.6	0.0	0.0	14.3	71.4	42.9	85.7	57.1	57.1	42.9	42.9	85.7	85.7	100.0	85.7	100.0	85.7	100.0	100.0	57.1	28.6	62.3	
5-day	100.0	42.9	14.3	0.0	0.0	14.3	71.4	85.7	85.7	100.0	71.4	71.4	57.1	57.1	100.0	85.7	85.7	100.0	100.0	100.0	85.7	85.7	68.8	

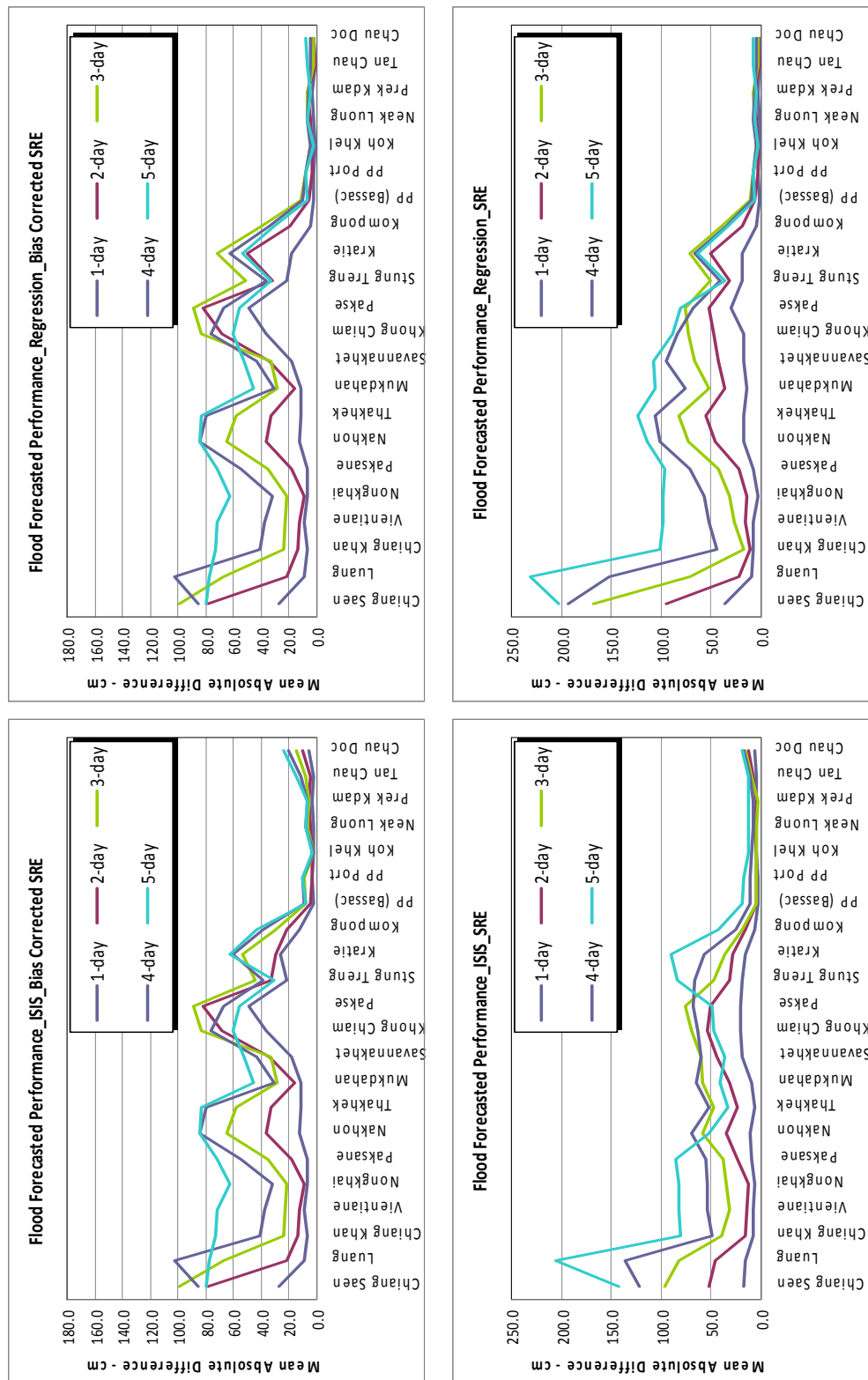


Figure 3-5 Forecast performance based on original result by URBS-ISIS and URBS-Regression using SRE and corrected SRE when GAEMI storm influenced to the LMB (04–06 October 2012).

Table 3-8 Achievement of daily forecast results against benchmarks (%) for URBS-ISIS and URBS-Regression using corrected SRE during GAEMI storm appearance (04–06 October 2012).

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannahet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average	
1-day	33.3	83.3	100.0	50.0	83.3	66.7	50.0	66.7	33.3	16.7	16.7	16.7	16.7	33.3	66.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	83.3	64.4
2-day	16.7	100.0	100.0	83.3	100.0	83.3	33.3	50.0	83.3	33.3	0.0	0.0	50.0	50.0	50.0	100.0	100.0	100.0	100.0	100.0	83.3	50.0	66.7	
3-day	16.7	33.3	100.0	50.0	83.3	50.0	0.0	0.0	50.0	33.3	0.0	16.7	50.0	0.0	50.0	66.7	66.7	100.0	100.0	100.0	50.0	33.3	47.7	
4-day	33.3	33.3	66.7	66.7	83.3	50.0	0.0	0.0	83.3	66.7	0.0	33.3	66.7	33.3	66.7	100.0	100.0	100.0	100.0	100.0	50.0	33.3	56.1	
5-day	50.0	50.0	16.7	33.3	16.7	33.3	16.7	16.7	50.0	50.0	33.3	33.3	100.0	50.0	66.7	100.0	100.0	100.0	100.0	100.0	83.3	50.0	56.8	
	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannahet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average	
1-day	33.3	83.3	100.0	50.0	83.3	66.7	50.0	66.7	33.3	16.7	16.7	16.7	33.3	33.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	67.4	
2-day	16.7	100.0	100.0	83.3	100.0	83.3	33.3	50.0	83.3	33.3	0.0	0.0	50.0	33.3	66.7	83.3	100.0	100.0	100.0	83.3	100.0	100.0	68.2	
3-day	16.7	33.3	100.0	50.0	83.3	50.0	0.0	0.0	50.0	33.3	0.0	16.7	33.3	16.7	16.7	50.0	66.7	100.0	83.3	83.3	100.0	100.0	49.2	
4-day	33.3	33.3	66.7	66.7	83.3	50.0	0.0	0.0	83.3	66.7	0.0	33.3	66.7	50.0	50.0	50.0	100.0	100.0	100.0	100.0	100.0	100.0	60.6	
5-day	50.0	50.0	16.7	33.3	16.7	33.3	16.7	16.7	50.0	50.0	33.3	33.3	83.3	50.0	83.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	59.8	

Table 3-9 Achievement of daily forecast results against benchmarks (%) for URBS-ISIS and URBS-Regression using SRE during GAEMI storm appearance (04–06 October 2012).

	Chang Saen	Chang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannahet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khei	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average	
1-day	50.0	100.0	100.0	66.7	100.0	66.7	50.0	33.3	50.0	33.3	50.0	16.7	50.0	0.0	50.0	100.0	83.3	100.0	100.0	100.0	100.0	100.0	83.3	67.4
2-day	16.7	100.0	100.0	66.7	83.3	66.7	50.0	16.7	50.0	16.7	33.3	33.3	33.3	33.3	50.0	83.3	100.0	66.7	100.0	83.3	100.0	50.0	60.6	
3-day	0.0	33.3	100.0	50.0	50.0	33.3	0.0	16.7	33.3	16.7	0.0	16.7	16.7	33.3	33.3	66.7	83.3	50.0	100.0	83.3	83.3	50.0	43.2	
4-day	0.0	16.7	66.7	66.7	50.0	33.3	0.0	0.0	33.3	0.0	33.3	50.0	50.0	33.3	50.0	50.0	100.0	33.3	100.0	100.0	66.7	33.3	43.9	
5-day	0.0	0.0	16.7	16.7	33.3	33.3	0.0	0.0	0.0	0.0	16.7	33.3	50.0	16.7	33.3	33.3	83.3	100.0	100.0	100.0	100.0	50.0	40.2	

	Chang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannahet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khei	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average
1-day	50.0	100.0	100.0	66.7	100.0	66.7	50.0	33.3	50.0	33.3	50.0	16.7	50.0	16.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	72.0
2-day	16.7	100.0	100.0	66.7	83.3	66.7	50.0	16.7	50.0	16.7	33.3	33.3	50.0	33.3	66.7	83.3	100.0	100.0	100.0	83.3	100.0	100.0	65.9
3-day	0.0	33.3	100.0	50.0	50.0	33.3	0.0	16.7	33.3	16.7	0.0	16.7	16.7	16.7	16.7	50.0	66.7	100.0	83.3	83.3	100.0	100.0	44.7
4-day	0.0	16.7	66.7	66.7	50.0	33.3	0.0	0.0	33.3	0.0	33.3	50.0	83.3	50.0	50.0	50.0	100.0	100.0	100.0	100.0	100.0	100.0	53.8
5-day	0.0	0.0	16.7	16.7	33.3	33.3	0.0	0.0	0.0	0.0	16.7	33.3	83.3	50.0	66.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	47.7

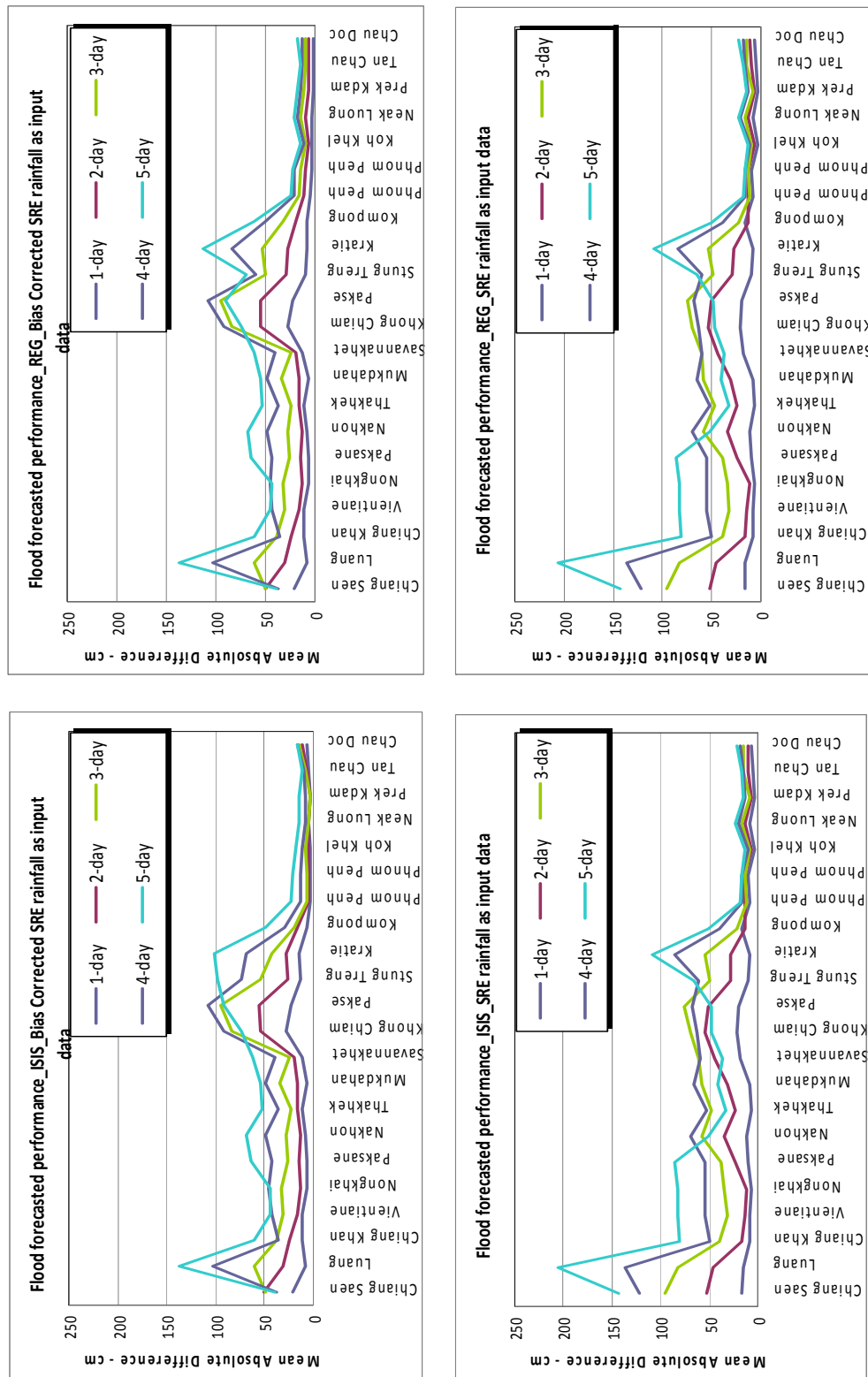


Figure 3.1: Forecast performance based on original result by URBS-ISIS and URBS-Regression using corrected SRE and SRE when Critical ITCZ influenced to the LMB (03-09 September 2012).

Table 3-10 Achievement of daily forecast results against benchmarks (%) for URBS-ISIS and URBS-Regression using corrected SRE during Critical ITCZ influenced to the LMB (03-09 September 2012).

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average	
1-day	71.4	100.0	100.0	71.4	71.4	100.0	57.1	42.9	85.7	57.1	14.3	42.9	42.9	42.9	71.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	71.4	74.7
2-day	57.1	85.7	100.0	85.7	100.0	85.7	100.0	100.0	85.7	71.4	14.3	14.3	57.1	42.9	85.7	100.0	100.0	85.7	85.7	100.0	71.4	57.1	76.6	
3-day	71.4	42.9	57.1	42.9	28.6	42.9	42.9	42.9	42.9	42.9	14.3	14.3	14.3	28.6	71.4	85.7	85.7	71.4	85.7	100.0	57.1	14.3	50.0	
4-day	85.7	42.9	57.1	71.4	42.9	57.1	57.1	85.7	42.9	57.1	42.9	14.3	42.9	57.1	57.1	28.6	100.0	42.9	100.0	100.0	42.9	14.3	56.5	
5-day	71.4	42.9	28.6	57.1	57.1	28.6	28.6	57.1	28.6	57.1	42.9	42.9	28.6	28.6	57.1	57.1	57.1	71.4	100.0	85.7	85.7	85.7	54.5	
	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average	
1-day	71.4	100.0	100.0	71.4	71.4	100.0	57.1	42.9	85.7	57.1	14.3	42.9	71.4	85.7	85.7	85.7	85.7	100.0	100.0	100.0	100.0	100.0	78.6	
2-day	57.1	85.7	100.0	85.7	100.0	85.7	100.0	100.0	85.7	71.4	14.3	14.3	57.1	71.4	71.4	57.1	57.1	85.7	57.1	85.7	100.0	100.0	74.7	
3-day	71.4	42.9	57.1	42.9	28.6	42.9	42.9	42.9	42.9	42.9	14.3	14.3	28.6	42.9	42.9	42.9	57.1	57.1	42.9	42.9	28.6	71.4	42.9	
4-day	85.7	42.9	57.1	71.4	42.9	57.1	57.1	85.7	42.9	57.1	42.9	14.3	28.6	42.9	71.4	28.6	71.4	42.9	71.4	85.7	42.9	28.6	53.2	
5-day	71.4	42.9	28.6	57.1	57.1	28.6	28.6	57.1	28.6	57.1	42.9	42.9	28.6	0.0	28.6	71.4	71.4	85.7	71.4	71.4	71.4	71.4	50.6	

Table 3-11 Achievement of daily forecast results against benchmarks (%) for URBS-ISIS and URBS-Regression using SRE during Critical ITCZ influenced to the LMB (03-09 September 2012).

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average
1-day	71.4	71.4	100.0	71.4	85.7	57.1	71.4	85.7	57.1	28.6	42.9	28.6	14.3	28.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	71.4	72.1
2-day	57.1	57.1	100.0	71.4	100.0	71.4	42.9	57.1	42.9	14.3	28.6	28.6	28.6	42.9	85.7	100.0	100.0	85.7	85.7	100.0	71.4	28.6	63.6
3-day	0.0	42.9	57.1	42.9	28.6	42.9	14.3	28.6	28.6	14.3	14.3	0.0	42.9	42.9	57.1	100.0	85.7	85.7	85.7	42.9	0.0	42.9	42.9
4-day	14.3	14.3	57.1	42.9	42.9	42.9	28.6	28.6	42.9	28.6	14.3	14.3	42.9	57.1	85.7	57.1	100.0	71.4	100.0	100.0	42.9	14.3	48.7
5-day	0.0	14.3	28.6	14.3	28.6	0.0	42.9	57.1	57.1	57.1	57.1	57.1	14.3	28.6	57.1	57.1	57.1	100.0	100.0	85.7	85.7	71.4	48.7
	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average
1-day	71.4	71.4	100.0	71.4	85.7	57.1	71.4	85.7	57.1	28.6	42.9	28.6	71.4	85.7	71.4	71.4	71.4	100.0	85.7	100.0	85.7	85.7	72.7
2-day	57.1	57.1	100.0	71.4	100.0	71.4	42.9	57.1	42.9	14.3	28.6	28.6	57.1	71.4	85.7	57.1	57.1	85.7	42.9	85.7	85.7	85.7	63.0
3-day	0.0	42.9	57.1	42.9	28.6	42.9	14.3	28.6	28.6	14.3	14.3	0.0	28.6	42.9	57.1	57.1	57.1	57.1	42.9	57.1	14.3	57.1	35.7
4-day	14.3	14.3	57.1	42.9	42.9	42.9	28.6	28.6	42.9	28.6	14.3	14.3	42.9	42.9	85.7	42.9	85.7	42.9	71.4	100.0	28.6	14.3	43.5
5-day	0.0	14.3	28.6	14.3	28.6	0.0	42.9	57.1	57.1	57.1	57.1	57.1	28.6	28.6	42.9	85.7	85.7	100.0	71.4	85.7	57.1	57.1	48.1

i/ Forecast Accuracy during KAI-TAK storm appearance (13–19 August 2012)

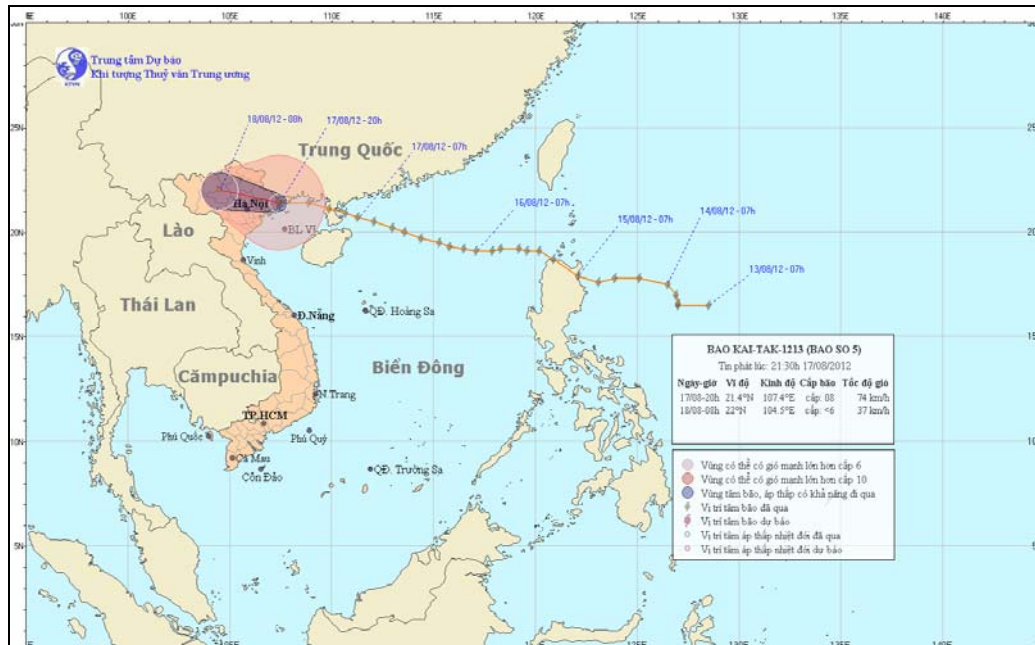


Figure 3-6 Track of Tropical storm KAI-TAK (13-19 August 2012).

The upper part of LMB from Chiang Sean to Luang Prabang was directly affected by the KAI-TAK tropical storm (see Figure 3-7). However intensive rainfall covering parts of area, caused water level rises in the upper and middle reaches and steady increases in the lower part of the LMB during mid-flood season 2012. See seasonal water level graphs at main stations in the Annex.

Through the performance forecast results, illustrated in Figure 3-4 and Table 3-6 and Table 3-7, the system provided a poor accuracy in the forecasted water levels at positions from Vientiane, Nakhon Phanom, Mukdahan, and Khong Chiam in the Upper and Middle reaches and from Kompong Cham to Koh Khel, Prek Kdam in the lower part to the Mekong Delta at Tan Chau/Chau Doc.

Figure 3-8 shows the hydrographs of observed water levels at some main stations in the Upper and Middle reaches and results for 1-5 day forecast lead time during 13–19 August 2012, the period of intensive rainfall occurrence in the LMB by influence by KAI-TAK, while low pressure occurred after the storm passed.

Although using both SRE and bias corrected SRE, the forecast for 2-5 day lead time couldn't catch properly the peak of the water level rising at Vientiane. It can be observed that forecast hydrographs using both SRE and bias corrected SRE show overestimated forecast values in comparison with the observed water levels. Besides that, the model URBS using both SRE and bias corrected SRE was not able to provide an accurate forecast of the recession at Nakhon Phanom and underestimated the water level.

Figure 3-9 presents forecast results of the MRCFFS for the Regression model applied in the downstream part at Kompong Cham. The difference between the observation and the

forecast shows that using both SRE and bias corrected SRE results in comparable results and tends to overestimate water level. The performance by percentile in Table 3-6 and Table 3-7 illustrate that Regression model with bias corrected SRE gives better results for 3-5 day forecast than those of Regression model with SRE.

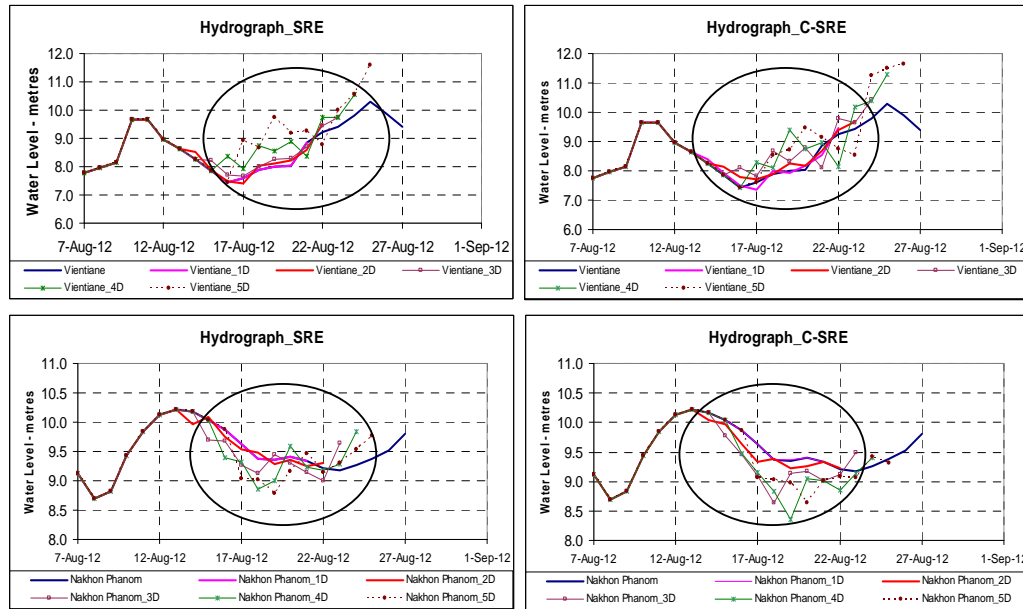


Figure 3-7 Hydrographs of observed water levels and 1-day to 5-day forecast lead time at main stations along Mekong River mainstream in the Upper and Middle reaches of LMB when using 2 different data sources (SRE and bias corrected SRE) during KAI-TAK storm appearance (13-19 August 2012).

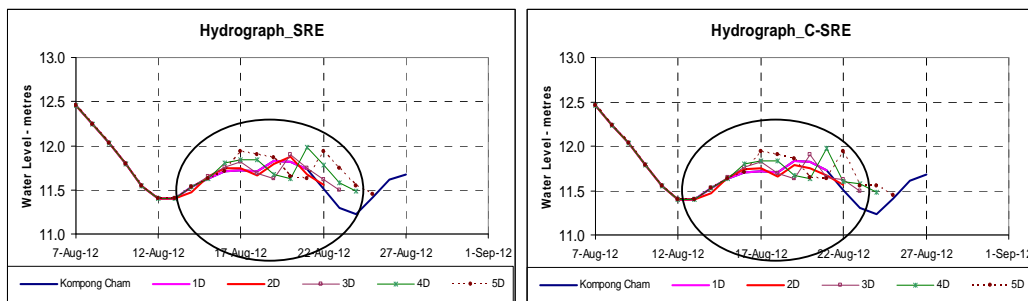


Figure 3-8 Hydrographs of observed water levels and 1-day to 5-day forecast lead time at downstream stations Kompong Cham by Regression model during KAI-TAK storm appearance (13-19 August 2012).

ii/ Forecast accuracy when GAEMI storm affected the LMB(04-06 October 2012)



Figure 3-9 Track of Tropical storm GAEMI (04-06 October 2012)

A tropical depression GAEMI upgraded to Tropical Storm on 04 October 2012 and landed over the Central of Viet Nam then downgraded to tropical depression on 06 October 2012 and finally to a low pressure area until 18 October 2012. Its effects combined with ITCZ and SW caused wide spread heavy rainfall over the middle and lower reaches of LMB and raised up water level at some stations in the lower reaches as Strung Treng down to Tan Chau/Chau Doc but those water levels were still below long term average water level.

Forecast results for 1-5 day forecast lead time at three stations along the lower reach of Mekong mainstream are presented in Figure 3-11. It can be seen that the URBS model provided a reliable accuracy for 1-day forecast (pink line); but for 2-5 day forecast the accuracies were less than expected. The difference between forecast and observation is larger when forecast time is longer.

One can see in Figure 3-11 that the forecasting results underestimate the water level; for Strung Treng station only the 1-day forecast is up to standard, while the 2 to 5-day forecasts are poor. However the 1 to 2-day forecast for Kratie and Kompong Cham stations are up to standard as well.

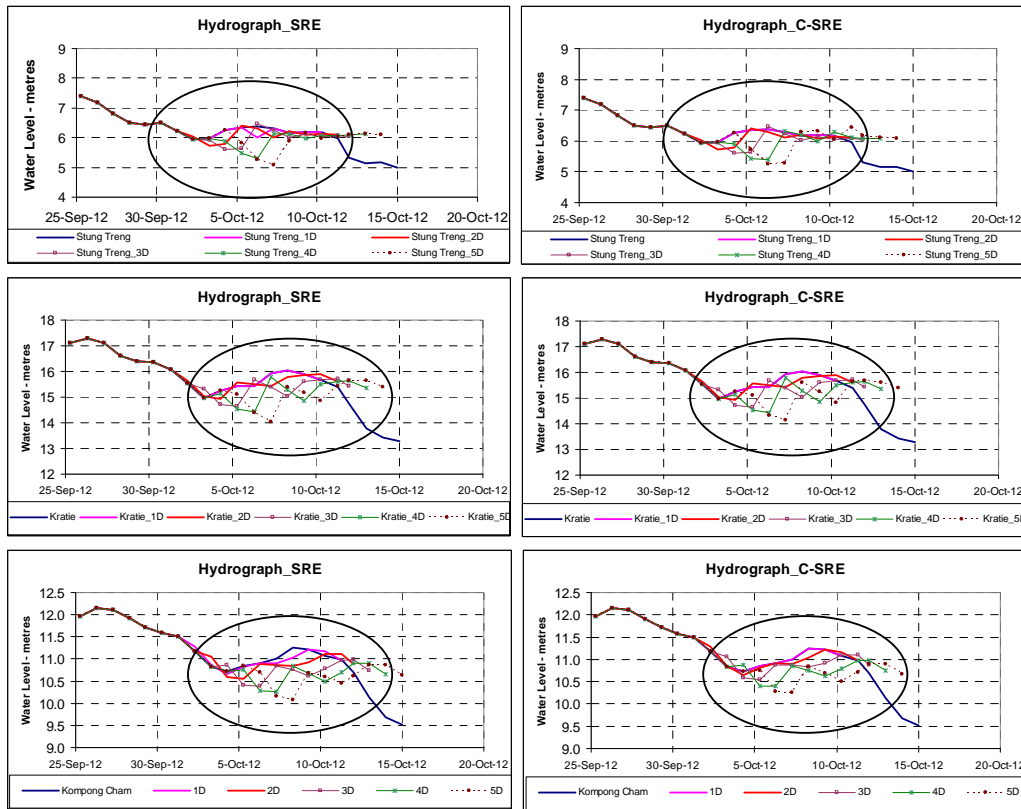


Figure 3-10 Hydrographs of observed water levels and 1-day to 5-day forecast lead time at stations along the Mekong River mainstream in the Lower Reach from Stung Treng to Kompong Cham, when the GAEMI storm affected the LMB.

lii/ Forecast accuracy during critical ITCZ appearance(3rd – 9th September 2012)

As a result of frequent ITCZ system appearance during the 03–09 September 2012, heavy rain covered both upper and middle parts of the LMB, especially from Luang Prabang to Sanannakhet/Mukdahan. This caused some rising water levels at stations in the upper and middle reaches of LMB and has less effect on the lower reach of LMB. Water levels at stations in the upper reach from Chiang Saen to Paksane are raised up but still lower than the long term average.

Figure 3-12 presents results for the 1-5 day forecast lead time at three main as Luang Prabang, Paksane and Kompong Cham. The URBS model was able to provide quite reliable forecasts for 1-day forecast lead time but not for 2-5 day forecast lead time. While the observed water levels at three represented stations were recessing, the trend of the 2-5 day forecast continued rising. Therefore the larger differences can be found when forecasting for longer lead times.

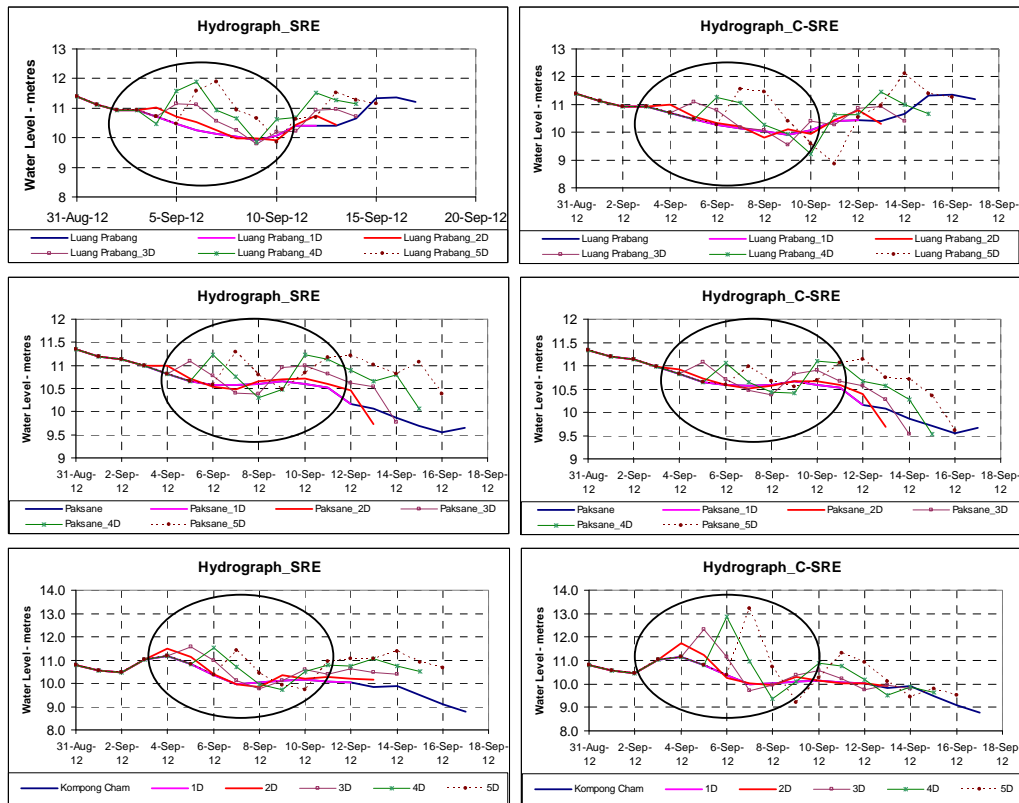


Figure 3-11 Hydrographs of observed water levels and 1-day to 5-day forecast lead time at main stations along the Mekong River mainstream for Luang Prabang, Paksane and Kompong Cham during ITCZ occurrence during 03–09 September 2012.

Through the evaluation of the forecast results for the entire flood season as well as for three critical weather situations in 2012, a number of specific problems related to system need to be considered:

- In forecasting for upper and middle reaches, the URBS is able to provide a reliable forecast result for 1-day lead time. However for 2-5 day lead times, the model has difficulty in forecasting “peaks” or “troughs”, especially when critical weather patterns occur.
- The regression model provides quite reliable forecast results than those of ISIS model at stations in the lower part of LMB and stations in the Mekong delta where there are tidal effects.
- Bias corrected SRE is a product that adjusted SRE data source using observed rainfall values of ground truth stations in LMB based on bias correction method. Therefore, both quality of observed data and density of station network in LMB will influence the accuracy of bias corrected SRE. When using bias corrected SRE forecast results at stations in the middle part from Nakon Phanom/Thakhet to Pakse show an overestimated trend, while forecast results by original SRE provided an underestimated trend. The sparse station network in the area is considered the main cause, which leads to this difference.

- During intensive rainfall caused by severe weather conditions, the system is able to provide forecasting trends in flood early warning effectively by using bias corrected SRE data.

3.3.2 Flood forecasting accuracy by using backup data source TRMM and comparison with SRE

As mentioned in paragraph 3.2, following recommendation of Dr. W.W. Immerzeel, senior international satellite precipitation expert, the flood forecasting team in the RFMMC tested the Tropical Rainfall Measuring Mission (TRMM), being another source of satellite rainfall, as input data for MRCFFS during 2012 flood season. Figure 3-13 shows the mean absolute differences in forecast performances of forecast results carried out by URBS – ISIS and URBS – Regression and the achievements by percentile are presented in Table 3-12 and Table 3-13.

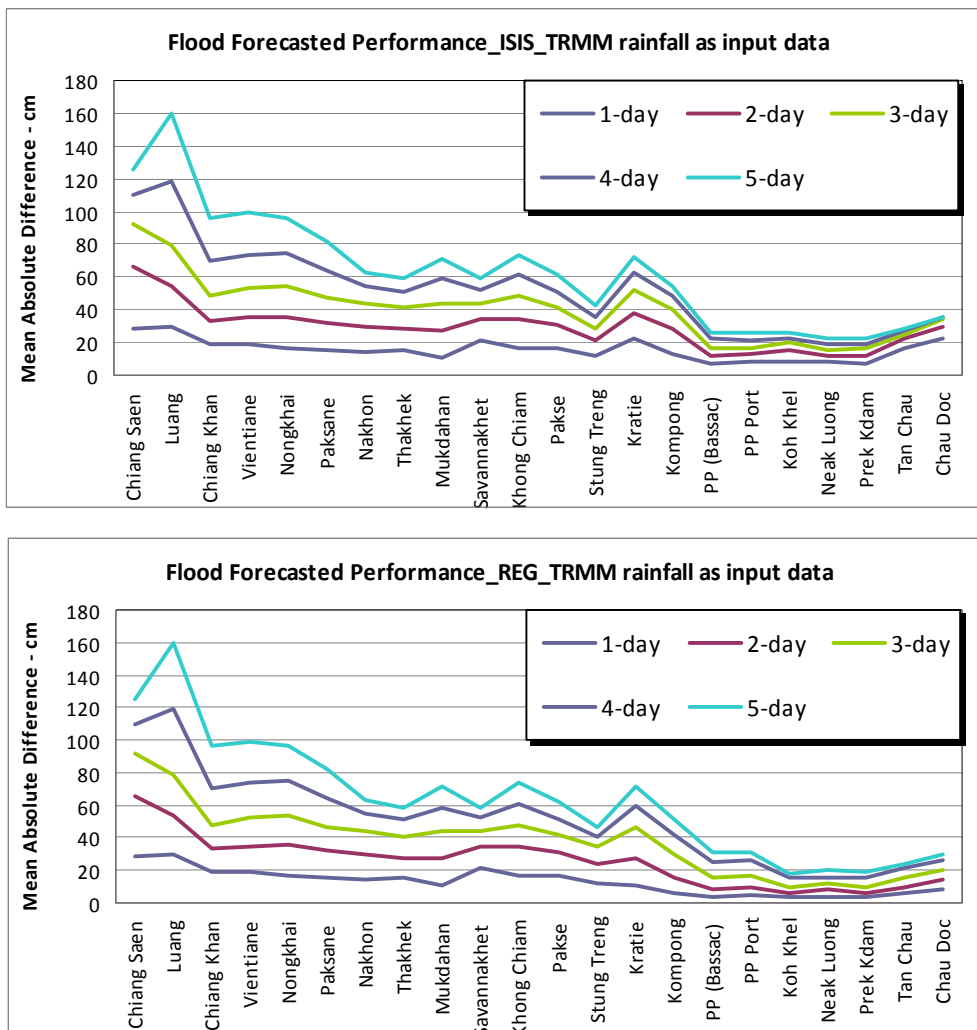


Figure 3-12 Forecast performance based on original result by URBS-ISIS and URBS-Regression using TRMM for the flood season 2012.

Table 3-13 Achievement of daily forecast against benchmarks (%)_Forecast result of URBS-Regression using TRMM.

	1-day	2-day	3-day	4-day	5-day
Chiang Saen	46.7	38.7	27.0	34.3	28.5
Luang Prabang	46.7	45.3	29.9	26.3	23.4
Chiang Khan	55.5	62.8	42.3	30.7	25.5
Vientiane	32.8	42.3	22.6	34.3	24.1
Nongkhai	30.7	35.0	23.4	31.4	30.7
Paksane	37.2	41.6	23.4	38.0	30.7
Nakhon Phanom	38.7	45.3	31.4	45.3	38.7
Thakhek	39.4	47.4	37.2	48.9	43.8
Mukdahan	42.3	51.1	34.3	43.8	37.2
Savannakhet	30.7	31.4	27.7	47.4	38.7
Khong Chiam	37.2	40.1	26.3	38.0	31.4
Pakse	31.4	42.3	33.6	48.2	35.0
Stung Treng	51.1	55.5	40.9	54.0	48.2
Kratie	56.9	54.0	32.8	44.5	38.0
Kompong Cham	67.2	67.2	46.7	54.0	46.0
P (Bassac)	70.8	59.9	34.3	19.7	38.0
P Port	69.3	56.9	32.1	49.6	39.4
Kohkhei	73.0	64.2	50.4	39.4	59.1
Neak Luong	67.2	55.5	42.3	59.1	54.7
Prek Kdam	73.0	62.0	48.2	65.7	59.9
Tan Chau	61.3	48.9	28.5	21.9	48.2
Chau Doc	57.7	40.9	26.3	15.3	42.3
Average	50.8	49.5	33.7	40.4	39.2

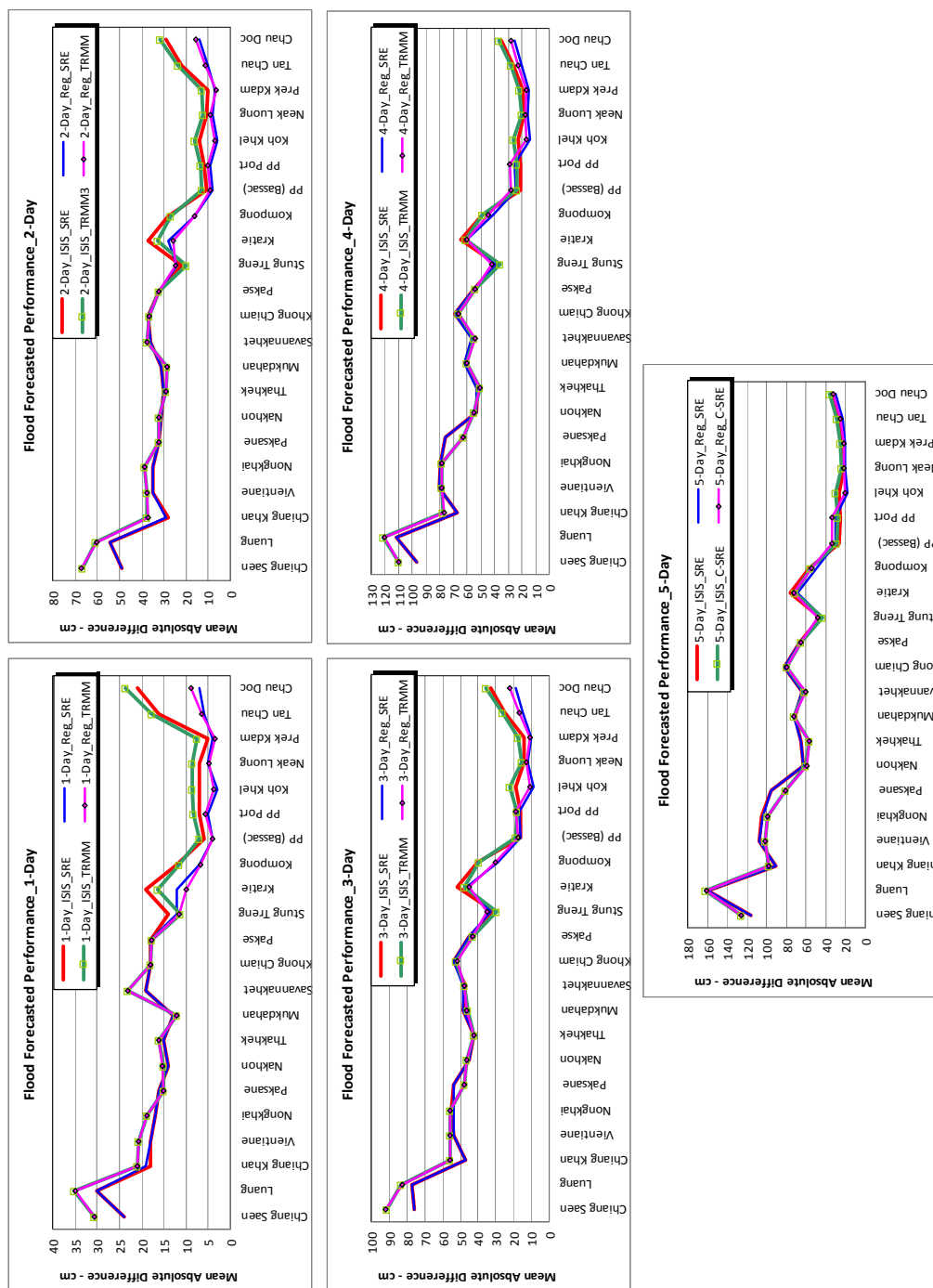


Figure 3-13 Forecast accuracy for 1-day to 5-day lead time at 22 main stations along the Mekong River mainstream during the flood season 2012; comparison between ISIS and Regression with 2 data sources (SRE and TRMM).

Based on the detailed forecast accuracies of SRE and TRMM for 1–5 day lead time at 22 main stations along the Mekong River mainstream, which are presented in Figure 3-1 and Figure 3-13, the use of TRMM as backup data source for the MRCFFS is recommended, however the following issues should be carefully taken into consideration:

- 1) When using the two data sources (SRE and TRMM), the forecast results at most forecast stations do not show huge differences for all forecast lead time;
- 2) TRMM can be downloaded for free from the ftp address of JAXA. However the data collection is sometimes interrupted by poor connection or maintenance periods leading to discontinuity of the time series of the TRMM data source.
- 3) The original TRMM format cannot be used directly as input to the system. Therefore it takes time to convert TRMM-time-series into the ASCII format, which can be read by FEWS instead of the original files.

3.3.3 Flood forecasting accuracy for 10 day forecast lead times

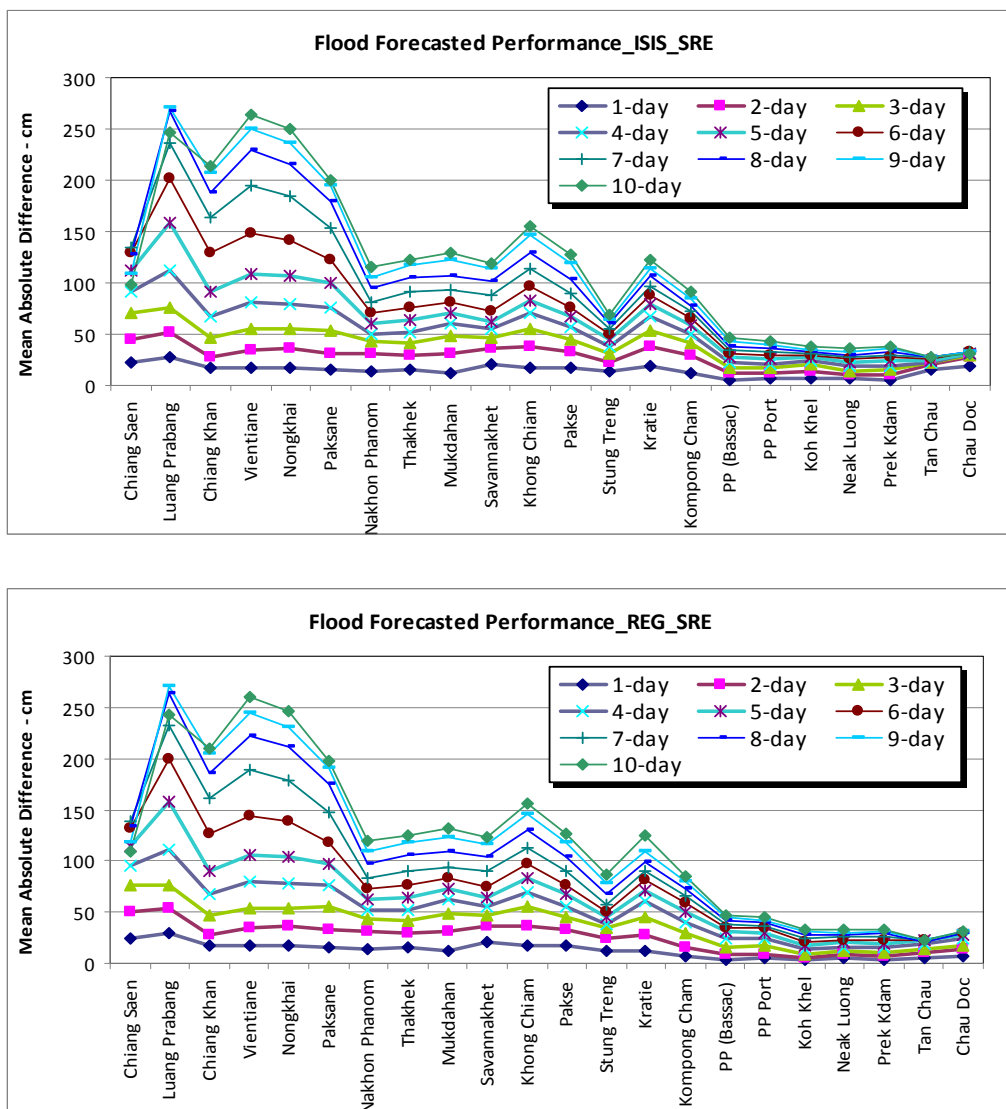


Figure 3-14 Forecast performance for 10-day lead time by URBS-ISIS and URBS-Regression models with SRE as rainfall input for the flood season 2012.

Table 3-14 Achievement of daily forecast results against benchmarks (%) using URBS-ISIS for 10-day lead time.

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannakhet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Kheh	Neak Lung	Prek Kdam	Tan Chau	Chau Doc	Average
1-day	64.2	60.6	69.3	37.2	42.3	42.3	51.8	42.3	53.3	42.3	40.1	37.2	41.6	28.5	58.4	81.8	73.7	76.6	70.1	83.9	56.9	40.9	54.3
2-day	63.5	56.9	80.3	43.8	43.1	48.2	54.0	49.6	56.2	43.1	45.3	51.1	64.2	39.4	55.5	58.4	52.6	48.2	61.3	61.3	43.8	27.7	52.2
3-day	46.7	34.3	62.0	29.9	25.5	21.9	38.0	32.1	39.4	29.9	25.5	38.0	48.9	28.5	36.5	43.8	40.1	40.1	52.6	47.4	34.3	21.9	37.2
4-day	51.8	36.5	44.5	33.6	32.8	32.8	57.7	57.7	52.6	51.8	42.3	50.4	68.6	46.0	61.3	29.9	62.8	31.4	71.5	66.4	34.3	19.7	47.1
5-day	31.4	21.9	32.8	26.3	20.4	18.2	51.1	45.3	40.9	46.7	31.4	36.5	61.3	38.7	52.6	53.3	53.3	59.9	65.0	59.9	59.1	46.0	43.3
6-day	35.8	21.9	29.2	27.0	23.4	29.2	63.5	51.8	50.4	58.4	41.6	48.9	77.4	49.6	44.5	49.6	51.1	53.3	59.9	57.7	56.9	41.6	46.5
7-day	34.3	17.5	27.0	13.9	13.9	16.1	51.1	43.8	45.3	47.4	29.9	39.4	69.3	46.7	42.3	46.7	47.4	54.7	57.7	53.3	59.1	46.0	41.0
8-day	37.2	12.4	27.0	16.8	17.5	21.9	56.9	51.8	50.4	51.8	36.5	46.0	78.8	54.7	36.5	46.7	44.5	51.8	53.3	51.8	54.7	48.9	43.1
9-day				14.6	13.9	20.4	50.4	47.4	46.7	47.4	31.4	39.4	78.8	46.7	49.6	40.1	65.0	49.6	70.1	69.3	56.2	48.2	46.6
10-day				13.1	15.3	21.9	50.4	46.7	39.4	47.4	31.4	39.4	74.5	44.5	45.3	36.5	62.0	46.0	68.6	65.7	57.7	51.8	45.1

Table 3-15 Achievement of daily forecast results against benchmarks (%) using URBS-Regression for 10-day lead time.

	Chiang Saen	Luang Prabang	Chiang Khan	Vientiane	Nongkhai	Paksane	Nakhon Phanom	Thakhek	Mukdahan	Savannahet	Khong Chiam	Pakse	Stung Treng	Kratie	Kompong Cham	PP (Bassac)	PP Port	Koh Khel	Neak Luong	Prek Kdam	Tan Chau	Chau Doc	Average
1-day	66.4	61.3	71.5	39.4	43.1	43.8	53.3	44.5	56.9	42.3	41.6	40.1	58.4	60.6	85.4	92.0	89.8	94.9	85.4	94.2	83.2	79.6	64.9
2-day	63.5	56.9	83.2	45.3	44.5	49.6	56.2	51.8	59.1	45.3	48.2	54.0	66.4	59.9	84.7	76.6	75.9	84.7	70.8	82.5	66.4	59.1	62.9
3-day	46.7	35.8	64.2	32.1	27.7	21.9	38.7	34.3	42.3	33.6	28.5	41.6	47.4	40.1	59.1	44.5	42.3	73.0	61.3	64.2	46.0	46.0	44.2
4-day	51.8	37.2	45.3	38.7	36.5	34.3	59.1	59.9	54.7	54.0	46.0	54.0	70.8	58.4	70.8	26.3	67.2	55.5	79.6	86.1	35.8	28.5	52.3
5-day	31.4	23.4	34.3	29.9	23.4	20.4	51.8	46.7	42.3	48.2	34.3	39.4	65.0	50.4	60.6	51.1	51.8	81.0	73.7	78.1	67.2	62.0	48.5
6-day	38.0	23.4	30.7	31.4	27.0	32.8	65.0	54.0	51.1	59.1	43.8	51.1	75.2	56.2	56.9	46.7	48.2	76.6	67.2	68.6	66.4	57.7	51.2
7-day	35.8	19.7	28.5	16.8	16.8	20.4	51.1	45.3	46.0	47.4	30.7	40.9	69.3	51.1	50.4	45.3	41.6	68.6	63.5	62.8	68.6	56.9	44.4
8-day	38.7	13.9	28.5	20.4	20.4	25.5	57.7	54.0	51.1	52.6	38.0	47.4	78.8	64.2	42.3	43.8	40.9	60.6	58.4	57.7	69.3	55.5	46.4
9-day				16.8	15.3	23.4	51.1	48.2	48.2	48.2	32.1	41.6	70.1	56.9	56.9	42.3	64.2	54.0	79.6	79.6	69.3	58.4	50.3
10-day				15.3	16.8	24.1	51.1	47.4	40.1	48.2	31.4	40.1	68.6	49.6	51.8	38.0	62.8	50.4	81.0	79.6	65.7	52.6	48.1

Achievement of 10-day lead time forecast results from URBS-ISIS and URBS-Regression are presented in Table 3-14 and Table 3-15 with benchmarks of success using the new set of performance indicators shown in Table 3-16 (officially applied since flood season 2011 onward).

Based on 10-days MRCFFS forecast results over 5 months of the flood season 2012, a number of preliminary comments are presented:

- The MRCFFS can provide 10-day forecast lead time from Vientiane/Nong Khai to downstream at Tan Chau/Chau Doc in which forecast rainfall is provided by NWP (Numerical Weather Prediction model) with 7-day GFS grid format. However there is a lack of 3-day forecast rainfall, which will improve flood forecast results for 8–10 day lead time.
- The URBS results of flood forecast for 7–10 day lead time of stations at the Upper and Middle reaches, starting from Vientiane/Nong Khai to Pakse, were evaluated as “limited” in use. However the Regression model results at stations in the Lower Reach from Strung Treng to Phnom Penh Port/Phnom Penh Bassac are promising; it is expected that results will improve as soon as forecast results at upstream stations are improved.
- For downstream stations at Tan Chau and Chau Doc, which have significant tidal effects, both ISIS and Regression can forecast 6-10 day lead time with quite good results. But for short lead time, 1-5 day, the Regression model performs better than ISIS.

The evaluation for mid-term forecast in this report is based on result of the MRCFFS for the entire flood season 2012 and is considered a preliminary overview of comments. Further testing and simulation for each specific flood event will provide more in-depth findings.

4. Conclusions and Recommendation

4.1 Conclusion

The flood season 2012 was considered a dry year, as the Lower Mekong Basin (LMB) was faced with low water levels, even lower than the long term average (LTA) water level. Only the Nong Khai mainstream gauge station recorded a water level higher than alarm level, but recessed below the long term average water level at the end of the flood season. The 2012 flood situation in the LMB is quite similar to the year 1992. This report presents an evaluation of forecast result provided by the MRCFFS for the entire flood season 2012, and provides a deeper understanding through an analysis of forecast accuracies for three specific flood events during remarkable critical weather conditions.

In general, the system is able to provide reasonable reliable forecasts at locations in the lower, downstream part of the basin. However the accuracies of the forecast results at stations in the Upper and Middle Reach show limited reliability, especially during critical weather conditions even though three difference satellite data sources (SRE, bias corrected SRE being the prime data source, and TRMM as backup data source) are used as input for the MRCFFS. In case the forecasting results for stations in the Lower Reach and Mekong Delta based on original SRE are compared with results based on bias corrected SRE, bias corrected SRE performs better. However bias corrected SRE has not shown its superiority in the forecasting results for stations in the Middle Reach.

The forecast accuracies are influenced by the models being applied and rainfall input data being used. One can see that the accuracies are worse in the Upper and Middle Reaches of LMB. The sources of rainfall input are SRE, bias corrected SRE (with limited number of gauge rainfall network) and rainfall forecast provided by NWP. The limited reliability/quality of the data is the main reason leading to a high variability in forecast results, particularly at the Upper and Middle Reaches of LMB.

The accuracy of the final forecast product is determined by the quality of forecast adjustment, which is performed and decided by forecaster-in-charge. Therefore the forecasters-in-charge will base the flood forecast on his/her knowledge and understanding of the Lower Mekong Basin, his/her experience in the use of hydrological models, his/her awareness and understanding of both the strengths and the weaknesses of the MRCFFS in the RFMMC, as well as his/her expertise of hydrology in order to effectively evaluate and adjust the system forecast results in order to determine the “best” result for the MRC flood bulletin and public dissemination.

4.2 Recommendation

The following recommendations are presented:

1. To improve forecasting accuracies, continuous improvement of hydro-met network over the LMB is required by increasing the numbers of real-time rain gauges and

hydro gauges, particularly through installation of new real-time rain gauges and hydro gauges in the Middle Reach of LMB on the right-bank in Thailand territory and on the left-bank in Lao PDR territory, thereby increasing data frequency as well as the quality of data.

2. The RFMMC needs to recalibrate the URBS model for the Upper and Middle Reaches and the ISIS model for the Lower Reach of LMB in order to improve the forecasting accuracies.
3. Using bias corrected SRE in forecasting for stations in the lower part of LMB and Mekong Delta with in combination with URBS-Regression is recommended, especially during intensive rainfall occurrences. Through the performance evaluation above, forecast results by bias corrected SRE have shown advantages in comparing with the forecast results by original SRE and TRMM.
4. Further evaluation for the system's performance of the medium to long term forecasts using historically similar rainfall patterns. System forecast evaluation for specific flood events is recommended.
5. The rating curves used in the MRCFFS need to be re-evaluated and the RFMMC should come up with a single set of consistent ratings for forecasting purpose, since the current rating curves do not produce consist flood volumes along the mainstream of LMB.
6. Since the performances of the ISIS model in the Cambodian Floodplain and the Mekong Delta are worse than expected, the latest version of ISIS needs to replace the old version of ISIS in the MRCFFS. Test and simulations should be carried out to secure the MRCFFS improvements before the flood season 2013.
7. Further MRCFFS performance improvement for short term forecasting on both the Mekong River mainstream and tributaries.

**Annex 1 Seasonal Water Level Graphs at Forecast
Stations along the Mekong River mainstream**

