Mekong River Commission

Technical Division (TD)

Regional Flood and Drought Management Centre (RFDMC)

Evaluation Report on Flash Flood Guidance System for Flood Season 2019

Cover from 1st June – 31st December 2019

Draft Version

Prepared by

Regional Flood and Drought Management Centre

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Certification of Approval
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Evaluation Report on Flash Flood Guidance System for Flood Season 2019
Cover from 1st June – 31st December 2019

No	Name of Person	Position	Date	Signature
1.	Mr. Nguyen Quoc Anh	Operational Hydro-Meteorologist/Forecaster	30 April 2020	
2.				
3.				
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5.				

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List of Abbreviations

ASM	Average Soil Moisture
CNMC	Cambodia National Mekong Commission
FFG	Flash Flood Guidance
FFGS	Flash Flood Guidance System
FMAP	Forecast Mean Areal Precipitation
FTP	File transfer protocol
GHE	Global Hydro Estimator
GTS	Global Telecommunication System
HE-sat	Hydro-estimator Satellite Precipitation
HRC	Hydrological Research Centre in San Diego, California (USA)
Hydmet	Rainfall and water level station data transfer software (MRC)
ITCZ	Inter Tropical Conversion Zone
JMA	Japan Meteorological Agency
JTWC	Joint Typhoon Warning Center
LMB	Lower Mekong Basin
LNMC	Lao National Mekong Commission
MAP	Mean Areal Precipitation
MCs	MRC Members' Countries
MRC	Mekong River Commission
MRCFFGCS	Mekong River Commission Flash Flood Guidance Computational Server
MRCFFGDS	Mekong River Commission Flash Flood Guidance Dissemination Server
MRC-FFGS	MRC Flash Flood Guidance
MRC-FFS	Mekong River Commission Flood Forecasting System
MRCS	Mekong River Commission Secretariat
MWGHE	Micro-Wave Global Estimator
NCHMF	National Center Hydro-Meteorological Forecasting, Viet Nam
NLAs	National Line Agencies
NOAA	National Oceanic and Atmospheric Administration
OFDA	Office of US Foreign Disaster Assistance
RFDMC	Regional Flood Management and Mitigation Centre
TMD	Thai Meteorological Department
TNMC	Thailand National Mekong Commission
U.S.NWS	U.S. National Weather Service

USAID	US Agency for International Development
UTC	Coordinated Universal Time
VNMHA	Viet Nam Meteorological and Hydrological Administration
VNNMC	Viet Nam National Mekong Commission
WMO	World Meteorological Organization

1. Introduction

As in many parts of the world, flash floods are destructive in the countries of the Lower Mekong River Basin (LMB). To respond to regional and national needs and in order to address the problem of flash floods in each member state of the MRC, the Mekong River Commission (MRC) and the US Agency for International Development (USAID), the Office of US Foreign Disaster Assistance (OFDA), with the technical support from the Hydrologic Research Centre (HRC), through a program with the U.S. National Weather Service (U.S.NWS), have jointly implemented a flash flood mitigation program in Cambodia, Lao PDR, Thailand, and Vietnam.

The MRC Flash Flood Guidance System (MRCFFGS) is designed as a diagnostic tool for meteorological and hydrologic services to analyses weather-related events that can initiate flash floods (e.g., heavy rainfall, rainfall on saturated soils) and then importantly to make a rapid evaluation on the potential for a flash flood for a location inside LMB. The system provides values of flash flood guidance and flash flood threat for small stream basins - the basins most prone to flash flooding. Evaluations of the threat of flash flooding may provide estimations from one-hourly to six-hourly time scales (depending on timely reporting of hydrometeorological data).

The system has been started to develop since 2005 and fully completed in August 2009 including the capacity building for the MRCFFGS operators at 4 National Line Agencies (NLAs). From 2009 to now, the system has been improved and developed, especially since the beginning of 2018, the system has implemented the bias correction of high-resolution satellite rainfall for putting it into the system's models. And in August 2019, the HRC completed and provided the Map-Server console interface of MRCFFGS to RFDMC. It is very visually for forecasters to directly analyze the MRCFFGS's products on the Map during routine work on Flash Flood operation for the LMB. Today the system has two console interfaces for FFG operation, they are user-friendly interface (See figure 1-1, and figure 1-2), also provides a lot of essential products to support the forecasters.

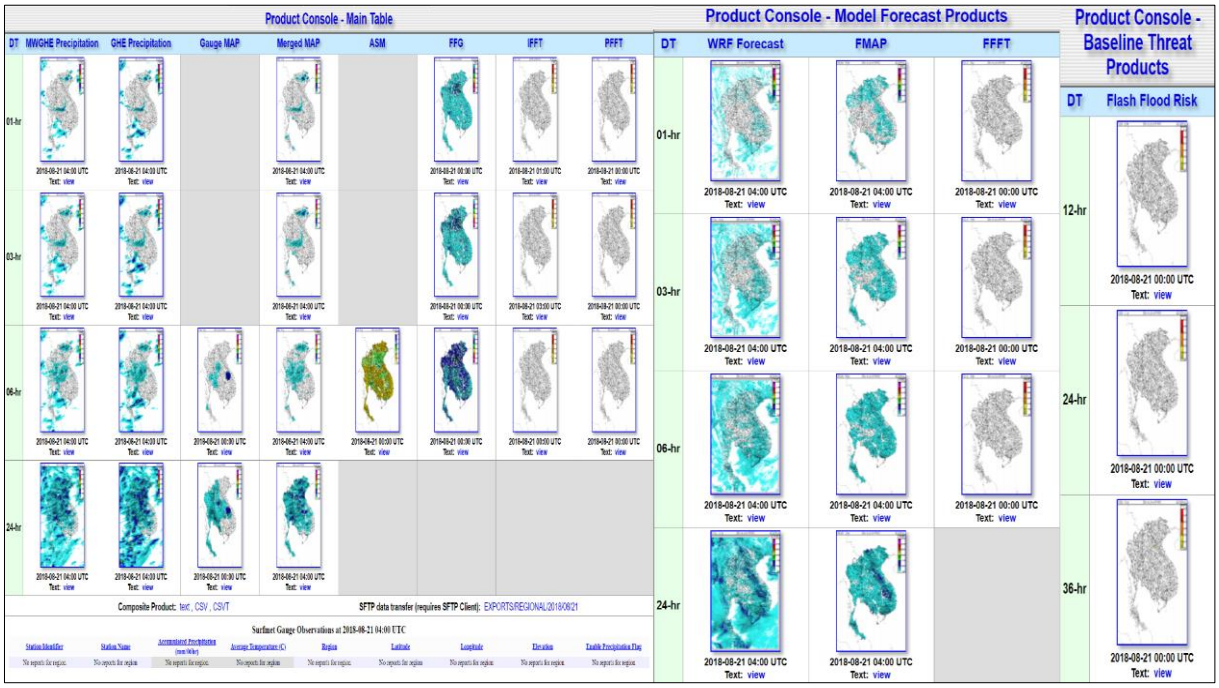


Figure 1-1: MRCFFG dissemination server user interface.

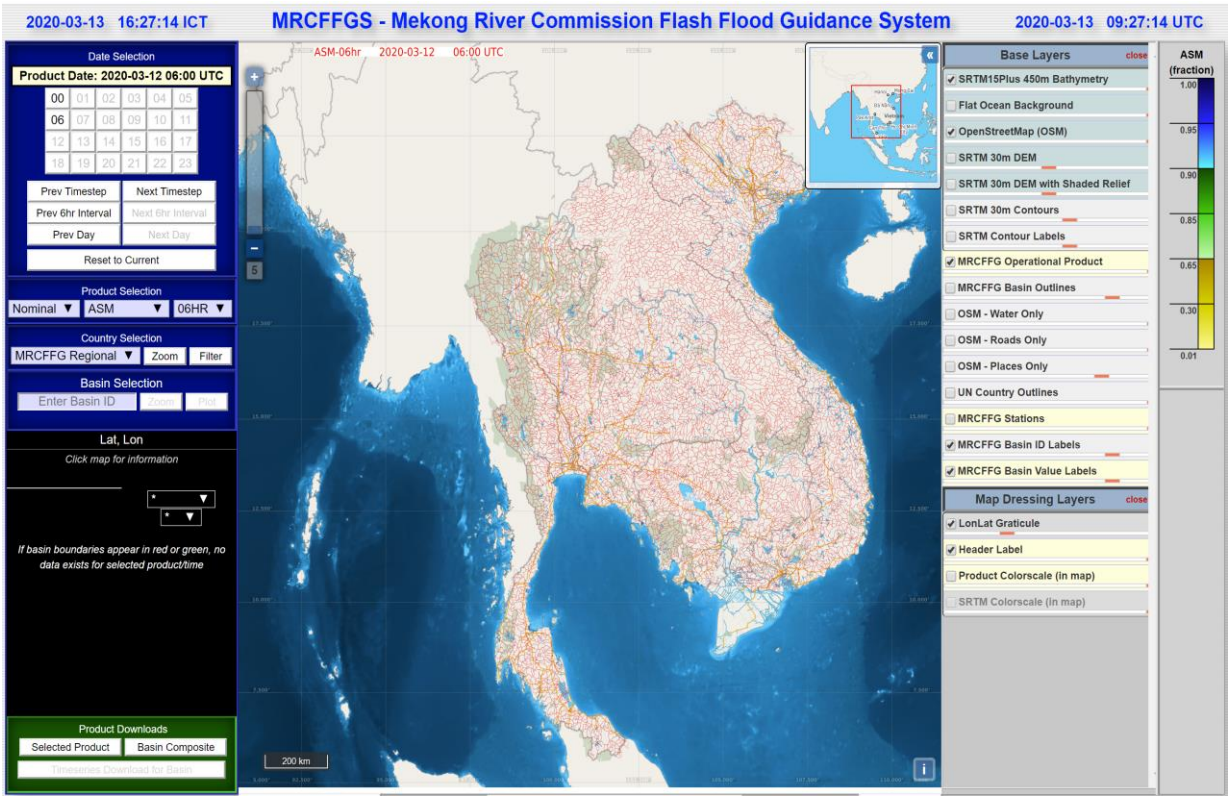


Figure 1-2: MRCFFGS Map-Sever interface console

The MRCFFG system model is a soil accounting model that needs satellite rainfall estimates as input data and the output is a warning for the next 1 hour, 3 hour and 6 hours for basins with a mean area of approximately 150-200 km2 in size that have a plausible chance of suffering from flash floods. The rainfall threshold needed to release a warning depends on the hydrological characteristics of the watershed. This threshold or FFG

number is the volume of rainfall of a given duration (1-6 hours) over a given small catchment that is just enough to cause bank-full flow at the outlet. The primary purpose of the MRCFFG system is to provide near real-time information guidance products pertaining to the imminence of potential small-scale flash flooding. The system provides the necessary products to support the development of warnings for flash floods from intense rainfall events with satellite and gauge-based rainfall estimates (see Figure 1-3: The key technical Components of Flash Flood Guidance System)

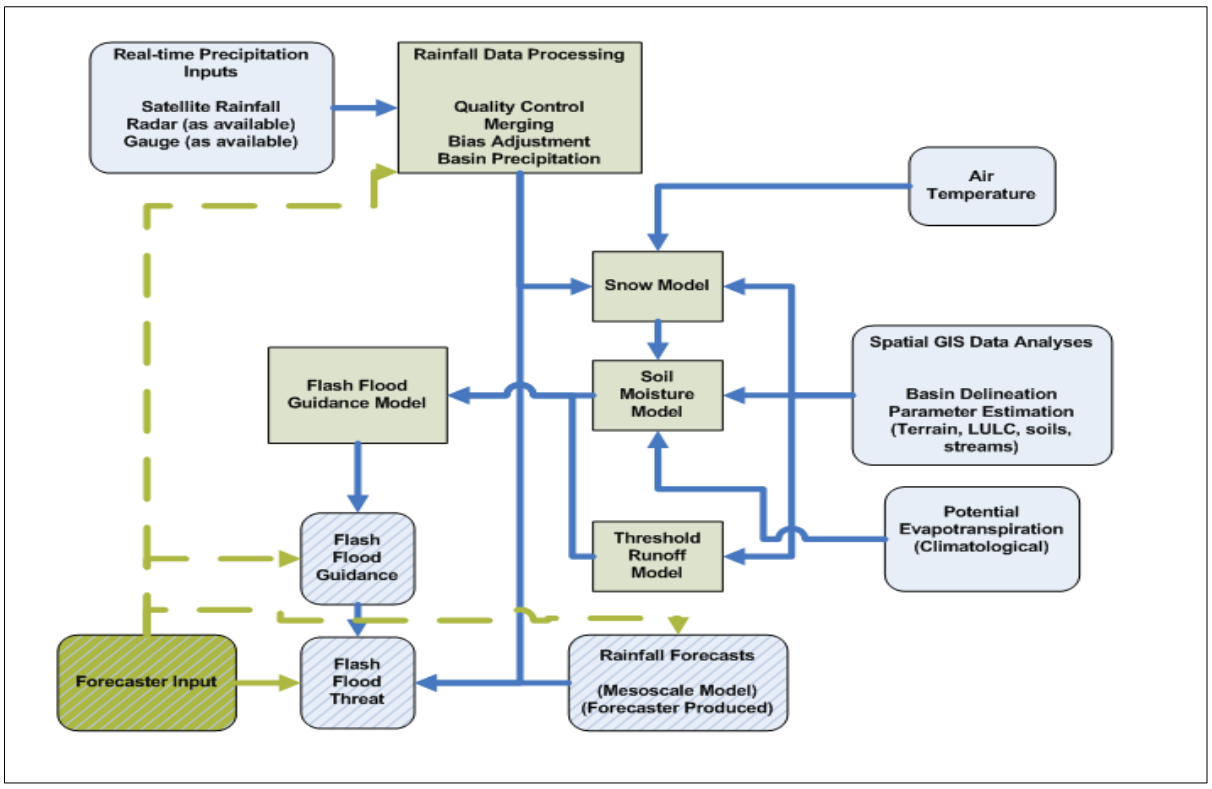


Figure 1-3: Key Technical Components for Flash Flood Guidance System

(Source: HRC)

The MRCFFG system is designed to provide FFG information on a small basin scale across the four riparian countries from various hydro-meteorological sources. FFG is an index that indicates how much rainfall is needed to cause minimal flooding in that basin. The FFG value indicates the total volume of rainfall over the given duration which is just enough to cause bank-full flow in the draining stream outlet. Consequently, rainfall volumes of the same duration that are greater than the FFG value indicate a likelihood overbank flows at the draining stream outlet. The FFG warnings scale is shown in figure 1-4.

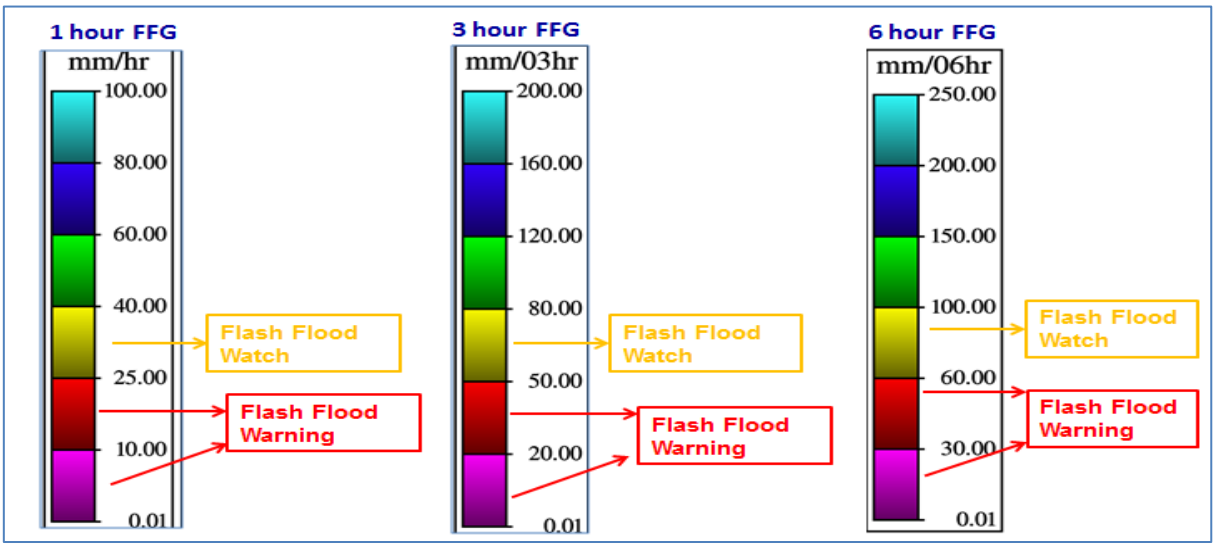


Figure 1-4: FFG warnings scale

The computer server was installed and located in RFDMC since mid – May 2018, during the 2019 flood season, the forecaster of RFDMC has continued operating routinely the MRCFFG system daily for the provision of flash flood guidance products. The information on flash flood risk areas that were detected by the MRCFFG system was uploaded on the MRC flood forecasting webpage in parallel with the river flood forecast (see Figure 1-, Figure 1-2). The warning that the MRCFFG system has identified as being 'critical' is daily collected in the excel and Google Earth KML format file can be downloaded from its website (see figure 1-5). Information regarding 'critical' weather conditions and risk of flash floods is disseminated through e-mail to alert the national line agencies, NGOs and the public at large.

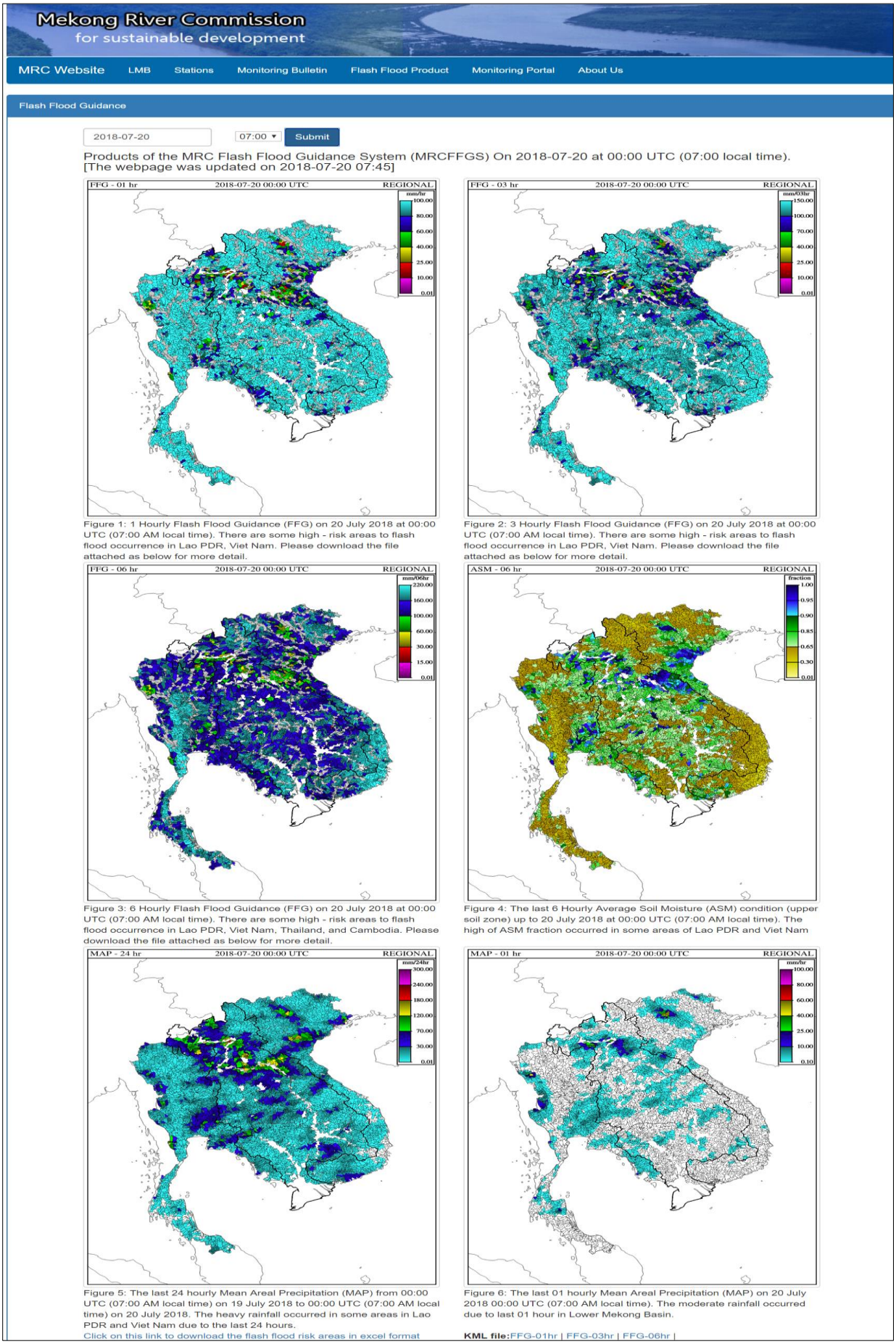


Figure 1: 1 Hourly Flash Flood Guidance (FFG) on 20 July 2018 at 00:00 UTC (07:00 AM local time). There are some high - risk areas to flash flood occurrence in Lao PDR, Viet Nam. Please download the file attached as below for more detail.

Figure 2: 3 Hourly Flash Flood Guidance (FFG) on 20 July 2018 at 00:00 UTC (07:00 AM local time). There are some high - risk areas to flash flood occurrence in Lao PDR, Viet Nam. Please download the file attached as below for more detail.

Figure 3: 6 Hourly Flash Flood Guidance (FFG) on 20 July 2018 at 00:00 UTC (07:00 AM local time). There are some high - risk areas to flash flood occurrence in Lao PDR, Viet Nam, Thailand, and Cambodia. Please download the file attached as below for more detail.

Figure 4: The last 6 Hourly Average Soil Moisture (ASM) condition (upper soil zone) up to 20 July 2018 at 00:00 UTC (07:00 AM local time). The high of ASM fraction occurred in some areas of Lao PDR and Viet Nam

Figure 5: The last 24 hourly Mean Areal Precipitation (MAP) from 00:00 UTC (07:00 AM local time) on 19 July 2018 to 00:00 UTC (07:00 AM local time) on 20 July 2018. The heavy rainfall occurred in some areas in Lao PDR and Viet Nam due to the last 24 hours.
Click on this link to download the flash flood risk areas in excel format

Figure 6: The last 01 hourly Mean Areal Precipitation (MAP) on 20 July 2018 00:00 UTC (07:00 AM local time). The moderate rainfall occurred due to last 01 hour in Lower Mekong Basin.

Figure 1-5: Flash flood forecasting bulltin on website

The first evaluation report on MRCFFG system was issued in 2011. The report has been produced to evaluate the performance of MRCFFG system for the 2011 flood season from May until 31 October. The present report is the nineth evaluation report of MRCFFG system. **The main purpose of this report is to evaluate the performance the operation the MRCFFG system in MRC-RFDMC on flash flood warning for areas of the MRC member countries during flood season 2019;** the detection of the risk areas for potential flash floods during this flood season from May until the late of December.

Other hands, the briefing of the situation of hydro-meteorology features (e.g. heavy rainfall, typhoon, tropical storms, ITCZ) and conclusion, lesson-learn experiences of the special flash flood operation tasks for each flash flood event occurred in LMB in flood season 2019 also are displayed in this report.

2. Flash flood guidance daily operation approach in MRC-RFDMC

The MRC FFG system products of FFG, ASM are updated every 6 hours at 00:00; 06:00; 12:00 and 18:00 UTC or at 01:00; 07:00; 13:00; 19:00 local time as the time of LMB region are UTC+7hour (please find more detail about the MRCFFGS's products in the Annex …). Usually, the daily operation of FFG system should be started at 07:00 AM. The daily operation of the MRC-FFG system can be dividing into 4 steps as described in the below paragraph. Figure 2.1-1 presents the workflow of daily FFG operation.

2.1 Data and information collection and analysis:

This is the first and important step that FFG operator should be carried out in cooperation with the meteorologist. Started with the collection of weather information such as weather chart, tropical storm track and it prediction track for the next few hours, and conduct the analysis to define if there have any severe weather situation in the LMB region such a tropical storm, Inter-Tropical Conversion Zone (ITCZ), Low Pressure, Tropical Depression …. etc. And, the FFG operator needs to collect the near real-time rainfall data (satellite data and Global Telemetry System – GTS), which are available in the FFG system, to verify the weather information.

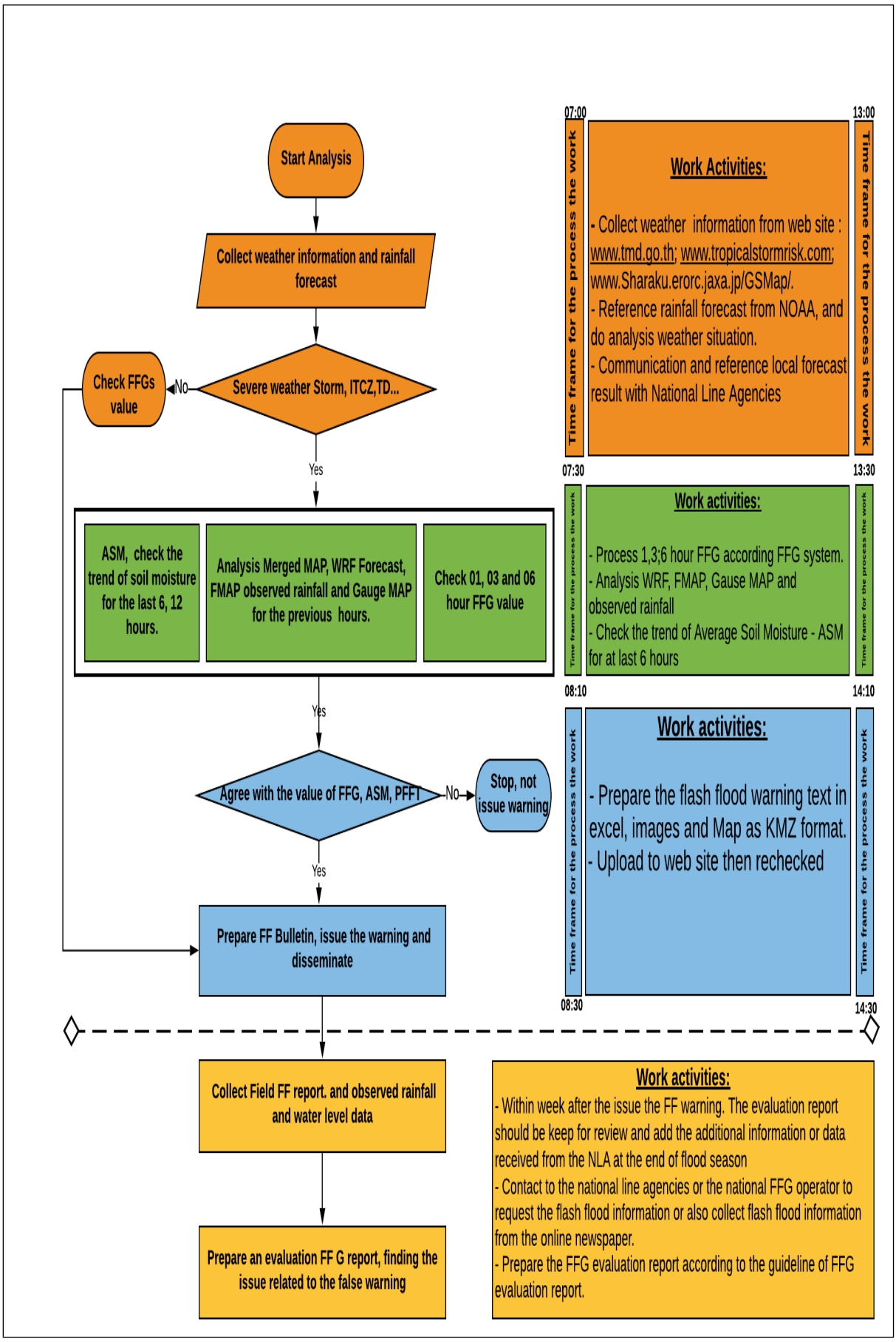


Figure 2.1-1: Workflow of daily operation of FFG system

2.2 FFG processing and analysis:

This step should be processed after finished weather analysis when FFG operator identified that weather condition in LMB is covered by bad weather condition, and the 1, 3 and 6 hours FFG map show the flash flood risk areas with the red color scale. The purpose of this step is to identify the location base on the ID of sub-basin in the MRCFFGS (provinces, district, villages) where most be a threat by the flash flood. The procedure to process the FFG has been provided in the Guideline for processing the MRC-FFG system.

Know the location of high-risk areas for the flash flood occurred (for 3-hour FFG). The FFG operator can do the next evaluation related to analysis the rainfall data at the surrounding of the flash flood risk areas by comparing the accumulated rainfall of three from the last 5 days of 3 difference rainfall data source such as Global Hydro Estimator (GHE) satellite rainfall estimate; MAP- Mean aerial precipitation; and observed rainfall from the ground stations of the Hydmet operational flood forecasting database. If FFG operator found that the accumulated rainfall from those 3 data sources significantly increased for the last 4 to 5 days, and the rainfall value for those data sources all most same (or have a small difference), which means the detection of the flash flood risk areas by FFG system is correct.

Other important factors such as soil moisture are also considered in this evaluation step, it is recommended that FFG operator should be closely working with the hydrologist to check the soil moisture condition that calculated by the FFG system is correct or wrong. Suggest that FFG operator should verify the trend of the soil moisture from the previous 06-hour until now if there significantly increase degree of saturation.

2.3 Prepare the Flash Flood bulletin and disseminate

After finished 2 evaluation step as mentioned in the above paragraph with the positive result (that means the FFG system is correct detect the flash flood risk areas), FFG operator continued with the preparation the flash flood warning bulleting in word format, then send it to the IT staff of RFDMC for uploading to the MRC flood web pages. An example of the FFG warning text has been provided in the Guideline of FFG system processing. The warning text file should be kept in the FFG operational folder for further analysis.

2.4 Collect the flash flood report for MRC-FFG System evaluation

This activity should be started immediately after provided the warning. The data information collection conducted by contact with the national line agencies (to the focal person who operated the FFG system at the national level), or it can be collected through the public media or the social network such as Facebook. The data and information should request to the national line agencies as below:

- Do there have any flash floods in the areas where the FFG system detected and warned? If there have a flash flood in this region which location and time it was happening (provide the name of province district and commune).
- Rainfall data for 3-hour, 6-hour or 24-hour in the previous from 3 to 5 days at surrounding flash flood areas.
- Water level data (if available) with the record time step for 1-hour at the hydrological stations located downstream or close to the flash flood detected areas.
- Weather information during the period before the flash flood occurred in the areas where the flash flood happens.

3. Methodology to evaluate Flash Flood Guidance Product

3.1 Verification of flash flood warning

Many verification studies rely on a categorical approach that considers a range of values to be classified into a prescribed category. The categorical approach often refers to the occurrence or non-occurrence of a specific meteorological or hydrological event. The exact nature of the event must be clearly identified with respect to the event characteristics, spatial extent and time span. For instance, the forecast and observed time series pertaining to the occurrence of a flash flood event can be converted to a categorical time series that contain values of 1 and 0, with the former indicating occurrence and the later indicating non-occurrence in both observed and forecast/simulated time series. Basin on the guide from WMO that a commonly used evaluation metric to analyze or validate the relationship between two categorical variables is the contingency table.

Table 3.1-1: Contingency table for verification of flash flood warning.

a = Hits b= False alarms c= Misses d= Correct negatives		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	a	b	a+b
	No	c	d	c+d
	Total	a+c	d+b	a+b+c+d=n

Contingency is simple yes/no table where the rows represent forecast categories and the columns represent categories for observations.

- The "a=Hits" indicates the number of observed flash flood that were correctly forecast to be flash floods.
- The "b=False alarms" indicates the number of observed non-flash flood that had been incorrectly forecast to be flash flood, or false alarms
- The "c=Misses" indicates the number of observed the number of observed flash flood that ware forecast to be non – flash flood, or misses.
- The "d=Correct negatives" indicates the observed non- flash floods that were correctly forecast to be non-flash flood, or correct negativities.

Categorical statistics that can be computed from the yes/no contingency table above to verify of flash flood warning.

Probability of detection (PoD) or Hit Rate (HR):

$$\boldsymbol{PoD = HR = \frac{a}{a + c}}$$

The Hit Rate (HR) has a range of 0 to 1 with 1 representing a perfect forecast. It uses only observed events (indicates **a and c**) in the contingency table which is sensitive only to missed events and not false alarm. Therefore, the HR can generally be improved by systematically over forecasting the occurrence of the event. And, HR also is incomplete buy itself and should be used in conjunction with either the false alarm ratio or the false alarm rate.

False alarm ratio (FAR):

$$FAR = \frac{b}{a+b}$$

The false alarm ratio (FAR) is the ratio of the total false alarms (b) to the total events forecast (a + b). Its range is 0 to 1 and a perfect score is 0. It does not include c and therefore is not sensitive to missed events. The FAR can be improved by systematically under forecasting rare events. It also is an incomplete score and should be used in connection with the HR.

False alarm rate (FA) or Probability of false detection (PoFD):

$$FA = PoFD = \frac{d}{b+d}$$

The false alarm rate (FA) or probability of false detection (PoFD) is unfortunately often confused with the false alarm ratio (FAR). The FA/PoFD is simply the fraction of observed non-events that are false alarms. By contrast, the FA/FoFD is referenced to the total number of forecasts. It is the fraction of forecasts that were false alarms. The best score for the FA/PoFD is 0, that is, the wish is to have as few false alarms as possible. The FA is not often used by itself but rather is used in connection with the HR in a comparative sense. The HR is also referenced to the observations, specifically, the total number of observed events.

Threat score (TS) or Critical success index (CSI):

$$TS = CSI = \frac{b}{a+b+c}$$

The threat score (TS), or critical success index (CSI), is frequently used as a standard verification measure. It has a range of 0 to 1 with a value of 1 indicating a perfect score. The CSI is more complete than the HR and FAR because it is sensitive to both missed events and false alarms.

3.2 Method to estimate indicates for evaluation of flash flood in MRC-RFDMC

The methodology for evaluation of flash flood guidance is based on two concepts:

- The first concept evaluates the feed-back of the FFGS detected risk areas from the information sources like the media or the press. As the link between the regional flood center and the local people is not fully established, the feed-back information on flash flood areas was mainly collected from the national media, such as online newspapers.
- The second concept evaluates the FFG results through the recorded water levels that are available in the operational database of RFDMC. If MRCFFG system detected flash flood warnings in the sub-areas where the gauge station is available, the MRCFFG results can be evaluated by comparing with the water level data of the gauge station located in the downstream part of sub-catchments.

The record daily rainfall of observed stations, where available at the flash flood risk areas also used as the support data for evaluate the flash flood occurred. However, occasionally it is difficult to evaluate the FFG results using the media information, because flash floods occurred in areas that are difficult to access and why the reporting of FFG results is lacking. Although the MRCFFG system often successfully had indicated a flash flood risk in the flooded areas, database information of occurred flash floods was not accurate and complete, which makes validation of the system difficult.

4. Flash Flooding in the Mekong Region during the Flood Season 2019

4.1 Weather phenomena conditions during flood season 2019

The climate of the Mekong Basin is dominated by the Southwest (SW) Monsoon, which generates wet and dry season of more or less equal length (table 4.1-1). The monsoon season usually lasts from May until late September of early October. There is usually heavy rain (50 – 100 mm/day) over most of the region. Later in the season, tropical cyclone occurs over most much of the area so that August and September and even October (in the delta) are the wettest months of the year. The Northeast (NE) Monsoon, which sets in toward late October, bring lower temperature. Rainfall during the months of the NE Monsoon is generally confined to Viet Nam since the rest of the Lower Mekong region lies in the lee of Animate Mountains of the Central Highland.

Table 4.1-1: Generalized climate season in the Mekong River Basin

Cool/Cold			Hot/Dry		Wet					Cool/Cold	
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NE Monsoon			Transition		SW Monsoon					NE Monsoon	

Source: Overview of the Hydrology of the Mekong Basin, MRC - 2005

During the flood 2019 there were 29 tropical storms which developed over the Pacific Ocean and or over the East Sea (see table 4.1-2 and figure 4.1-1) There were **five** tropical storms, namely (1) MUN, (2) WIPHA, (3) PODUL, (4) MATMO, (5) NAKRI which caused serious flash floods affecting the LMB. The other cause of flash floods in the Lower Mekong region is the ITCZ, low pressure and tropical depression which also led to flash flood occurrence at some areas in the Mekong mainstream and its tributaries.

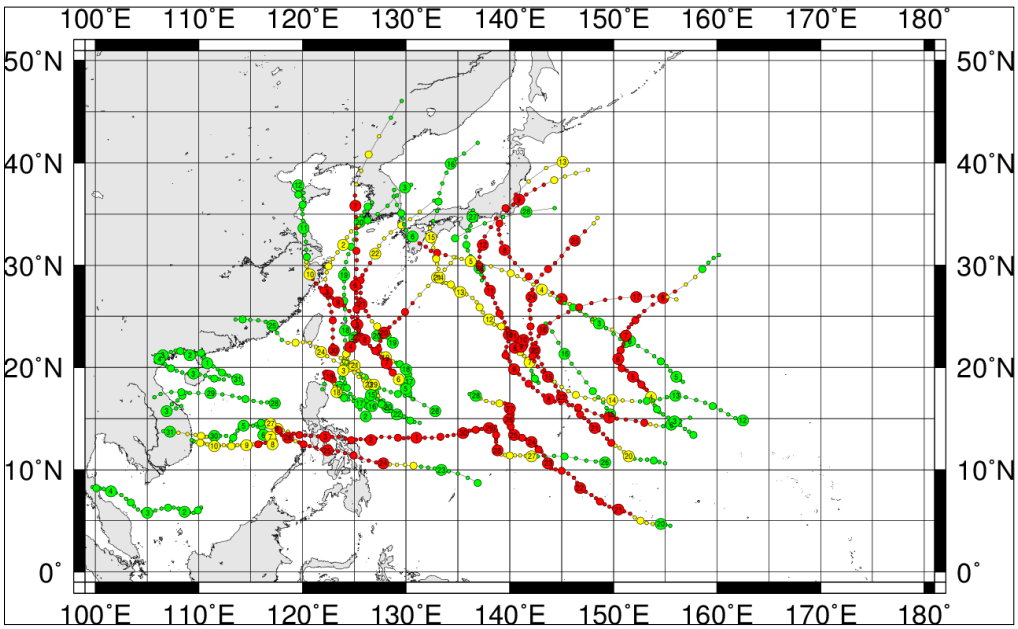


Figure 4.1-1 Tropical storm track for Western Pacific in 2019

(Source: Digital typhoon, National Institute of Informatics, Japan)

Table 4.1-2: Tropical storm track developed over the Pacific Ocean and East Sea during flood season 2019

No	Number	Name	Basin	Birth (UTC)	Death (UTC)	Duration	Min. Pres.
1	201901	PABUK	W. N. Pacific	1/1/2019 6:00	1/4/2019 18:00	3 Days 12 Hours	996
2	201902	WUTIP	W. N. Pacific	2/19/2019 18:00	2/28/2019 6:00	8 Days 12 Hours	920
3	201903	SEPAT	W. N. Pacific	6/27/2019 12:00	6/28/2019 6:00	0 Days 18 Hours	994
4	201904	MUN	W. N. Pacific	7/2/2019 6:00	7/4/2019 6:00	2 Days 0 Hours	992
5	201905	DANAS	W. N. Pacific	7/16/2019 6:00	7/20/2019 18:00	4 Days 12 Hours	985
6	201906	NARI	W. N. Pacific	7/25/2019 18:00	7/27/2019 6:00	1 Days 12 Hours	998
7	201907	WIPHA	W. N. Pacific	7/30/2019 18:00	8/3/2019 12:00	3 Days 18 Hours	985
8	201908	FRANCISCO	W. N. Pacific	8/2/2019 12:00	8/7/2019 0:00	4 Days 12 Hours	970
9	201909	LEKIMA	W. N. Pacific	8/4/2019 6:00	8/12/2019 18:00	8 Days 12 Hours	925
10	201910	KROSA	W. N. Pacific	8/6/2019 6:00	8/16/2019 12:00	10 Days 6 Hours	965
11	201911	BAILU	W. N. Pacific	8/21/2019 6:00	8/25/2019 18:00	4 Days 12 Hours	985
12	201912	PODUL	W. N. Pacific	8/28/2019 0:00	8/30/2019 0:00	2 Days 0 Hours	992
13	201913	LINGLING	W. N. Pacific	9/2/2019 0:00	9/8/2019 0:00	6 Days 0 Hours	940
14	201914	KAJIKI	W. N. Pacific	9/2/2019 12:00	9/3/2019 12:00	1 Days 0 Hours	996
15	201915	FAXAI	W. N. Pacific	9/4/2019 18:00	9/10/2019 0:00	5 Days 6 Hours	955
16	201916	PEIPAH	W. N. Pacific	9/15/2019 0:00	9/16/2019 12:00	1 Days 12 Hours	1000
17	201917	TAPAH	W. N. Pacific	9/19/2019 0:00	9/23/2019 0:00	4 Days 0 Hours	970
18	201918	MITAG	W. N. Pacific	9/28/2019 0:00	10/3/2019 6:00	5 Days 6 Hours	965
19	201919	HAGIBIS	W. N. Pacific	10/5/2019 18:00	10/13/2019 3:00	7 Days 9 Hours	915
20	201920	NEOGURI	W. N. Pacific	10/17/2019 0:00	10/21/2019 12:00	4 Days 12 Hours	970
21	201921	BUALOI	W. N. Pacific	10/19/2019 6:00	10/25/2019 12:00	6 Days 6 Hours	935
22	201922	MATMO	W. N. Pacific	10/29/2019 18:00	10/31/2019 6:00	1 Days 12 Hours	992
23	201923	HALONG	W. N. Pacific	11/2/2019 12:00	11/9/2019 0:00	6 Days 12 Hours	905
24	201924	NAKRI	W. N. Pacific	11/5/2019 18:00	11/11/2019 0:00	5 Days 6 Hours	975
25	201925	FENGSHEN	W. N. Pacific	11/12/2019 0:00	11/17/2019 12:00	5 Days 12 Hours	965
26	201926	KALMAEGI	W. N. Pacific	11/14/2019 12:00	11/20/2019 0:00	5 Days 12 Hours	975
27	201927	FUNG-WONG	W. N. Pacific	11/20/2019 0:00	11/22/2019 12:00	2 Days 12 Hours	990
28	201928	KAMMURI	W. N. Pacific	11/26/2019 0:00	12/5/2019 18:00	9 Days 18 Hours	950
29	201929	PHANFONE	W. N. Pacific	12/22/2019 12:00	12/28/2019 0:00	5 Days 12 Hours	970

(Source: Digital typhoon, National Institute of Informatics, Japan)

4.2 Briefing rainfall in the Mekong River in flood season 2019

The total rainfall in LBM in the flood season 2019 is less than the total rainfall of Long-Term Average (LTA/Mean) and it is unevenly distributed over time and space during flood season. Especially, regarding to the average cumulate daily rainfall recorded at mainstream stations of the LMB: over of LMB was lower more than 50% of LTA from June to July (see figure 4.2-1).

The middle region in the upper reaches between Laos and Thailand of the LMB has a total rainfall about LTA, the heavy rains were concentrated in August and September due to the influence of the southwest monsoon and storm circulation; the month average cumulative rainfall of August and September in this area exceeded 50% of total rainfall of LTA in the same period (see figure 4.2-1).

The lower part of the LMB of Cambodia and the Mekong Delta at Tan Chau and Chau Doc, the total rainfall was about or less than during the flood season in the LMB, the heavy rainfall concentrated in late August and early September as the same middle part.

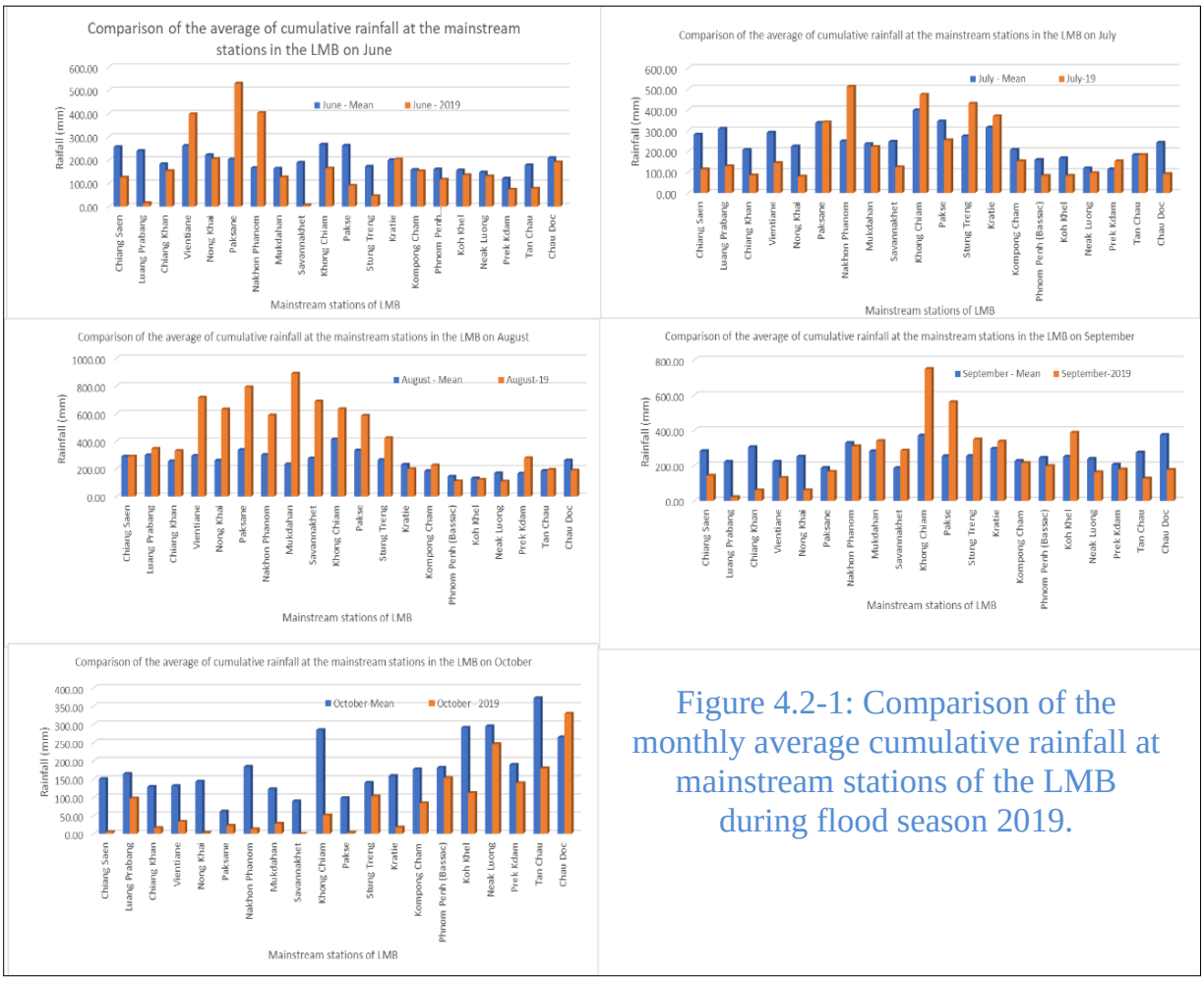


Figure 4.2-1: Comparison of the monthly average cumulative rainfall at mainstream stations of the LMB during flood season 2019.

4.3 Briefing flooding in Mekong River in flood season 2019

In LMB, the flood season 2019 came late and ended early about 3 weeks. Along the LMB mainstream, the low water level had occurred throughout the LMB (lower than LTA at 2-3 meters, especially, some stations the WL was lower than the lowest base on the historical data of 60 years); The deficient accumulation rainfall during the first three months of flood season 2019 (June to July) about 40 – 50 % compared with LTA from upper to Pakse (Lao PDR) in LMB was causing flow at those stations were reduced significantly (see figure 4.3.1-1).

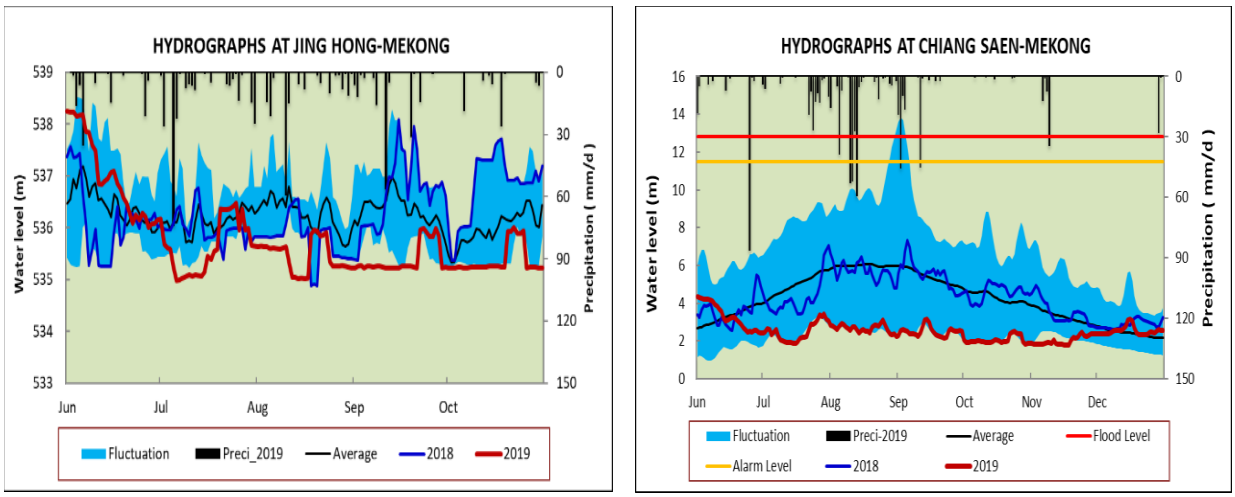


Figure 4.3-1: Hydrograph at Jing Hong (China) and Chiang Saen (Thailand)

The water level in the LMB was somewhat improved due to the contribution of water from local heavy rains in late August and early September due to expected by southwestern typhoons and monsoon; the hydrographic here reached the peak quickly but fall also quickly because it is created by local heavy rains without contributed by water from the upstream (the sharp flood shape - rapid rise and fall). Such as, at Khong Chiam (Thai Land) station reached 15.72 m at 07:00 AM on September 5, 2019 (higher than the flood warning level of 1.22 m - the flood alarm at the station is 14.50 m, lower than the historic highest flood level of 0.53 m (16.25m, 7:00 AM 16/9/200). At Pakse (Lao PDR), the water level reached 13.75 m at 07:00 Am on September 5, 2019 - higher than the 1.75 m of flood warning level (the flood alarm at the station was 12.00 m) and higher the highest flood level in history is 0.33 m (13.32 m on September 15, 2000). See figure 4.3-2.

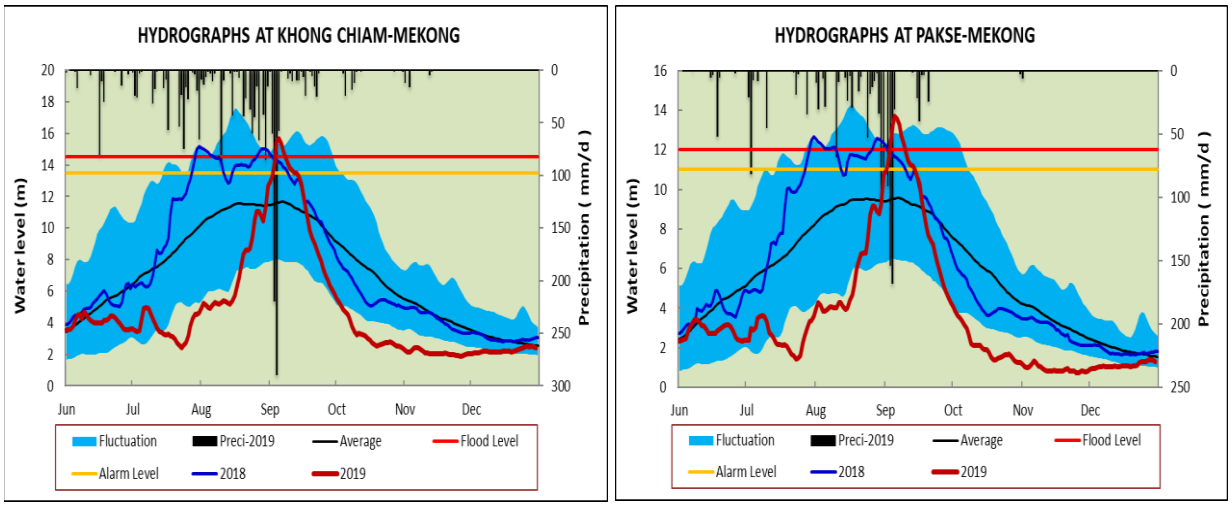


Figure 4.3-2 Hydrograph at Khong Chiam and Pakse in flood 2019

The decrease in the water from the upper of LMB as mentioned above has caused a serious decrease inflow across the Mekong basin at Tan Chau and Chau Doc stations (where the Mekong River flows) of Mekong Delta of Vietnam until mid- September 2019. The water level starting to fall below the level of LTA from June 18 and maintaining lower than the LTA about 0.5 -2.0 m. However, very fortunate that Mekong Delta of Vietnam at Tan Chau and Chau Doc received water from the upstream floods in Pakse so the flow in TC and Chau Doc also improved and reached higher Alarm level at Tan Chau (3.36 m on 17/9/2019) and Chau Doc (3,08 m on 17/9/2019). See figure 4.3-3.

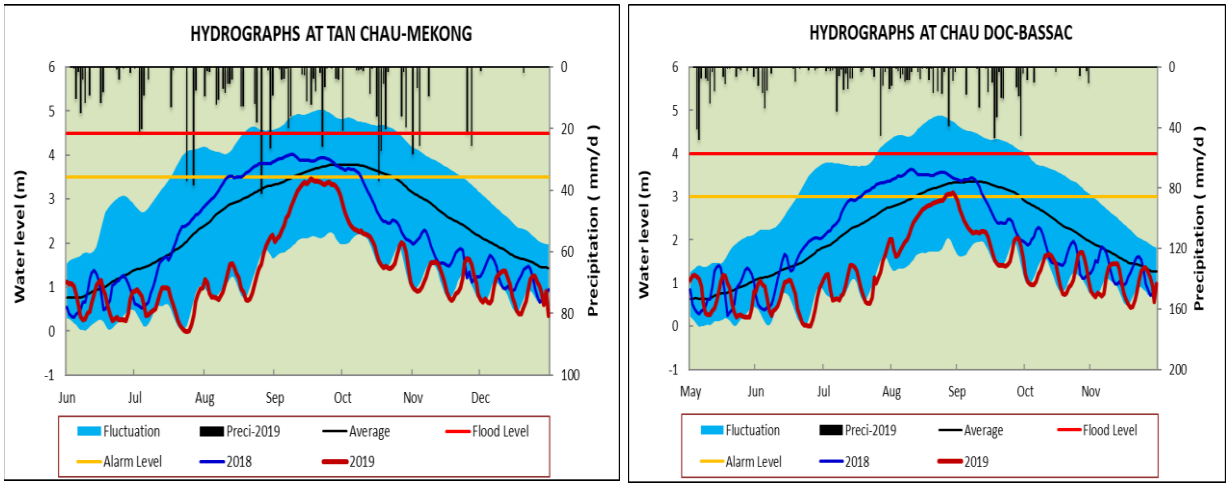


Figure 4.3-3: Hydrograph at Tan Chau and Chau Doc in flood season 2019

To sum up, the flood season in 2019 in the LMB with the water level at most of the monitoring stations were lower than LTA, even lower than lowest histories data in the last 60.3.3 Flash flood operation at RFDMC during flood season 2019

4.4 The flood flash operation at RFDMC during flood season 2019

As mentioned above that complicating of climate/weather situation during the flood season 2019 whereby the flash flood guidance operation in MRC-RFDMC for Mekong Region had has some features as follows:

- There are 230 bulletins of flash flood were summited with the average of achievement/verification of indicates to flash flood warning operation for LMB were shown in the table 4.4-1 as below. Please see annex D for achievement/verification in each country of LMB.

Table 4.4-1: Average verification flash flood warning in the LMB in flood season 2019

Hits rate (POD)	0.74
False Alarm Ratio (FAR)	0.36
False Alarm Rate (POFD)	0.02
Threat Score (TS)	0.30

- The total flash flood events across the Mekong region was 31 events, it is more than the LTA and more than 2018. Table shown total number and distributed space and time of flash flood events in flood season 2019 in the LMB (See table 4.4-2).
- Most high-intensity flash floods are mainly concentrated in the rainy months (from July to September) that effected by climatic conditions such as typhoons from Pacific Ocean as well as the East Sea, Southwest monsoon, ITCZ in the Mekong region (July and August). See figure 4.4-1 and figure 4.4-2.

Table 4.4-2: Distribution the flash flood events occurred in LMB, 2019

Month	FF events	Lao PDR	Thailand	Cambodia	Viet Nam
June	2	0	0	0	2
July	8	3	0	2	3
August	7	2	1	1	3
September	12	3	3	3	3
October	0	0	0	0	0
November	2	0	0	1	1
Total	**31**	**8**	**4**	**7**	**12**

- Especially in this flood season, even October is the time of flood season ended, to mid-November still appeared of typhoons on Southern of Vietnam, then its circulation caused heavy rainfall, therefore, a major flash flood occurred in Central Highlands part of

Vietnam. This unusual time and space of this weather element is also a special feature for the occurrence of flash floods in 2019.

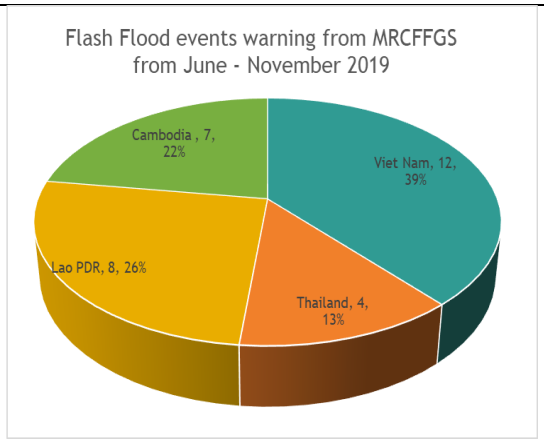


Figure 4.4-1: Flash flood events warned from MRCFFGS from June – November 2019

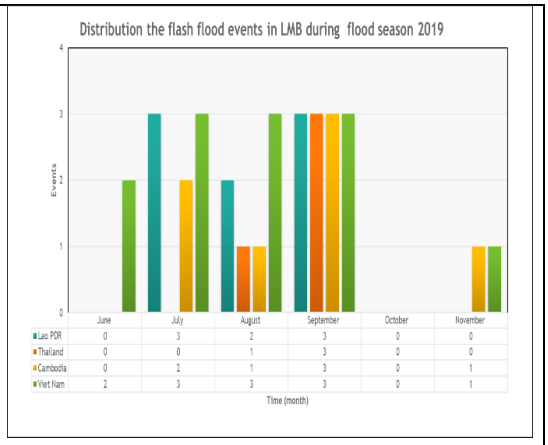


Figure 4.4-2: Distribution the majors flash flood events in LMB during flood season 2019

Table 4.4-3: Calendar date of flash flood recorded in the LMB during flood 2019

2019 June

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
27	28	29	30	31	01	02
03	04	05	06	07	08	09
10	11	12	13	14 V	15	16
17	18	19 V	20	21	22	23
24 V	25	26	27	28	29	30
01	02					

2019 July

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
01	02	03 V,L	04	05 L	06	07
08	09	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30 V,L,C	31 V,C	01	02	03	04
05 V	06					

2019 August

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
29	30	31	01	02	03	04
05 V-WIPHA	06	07	08	09	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29 V,L	30	31 V,L,T,C	01
02	03					

2019 September

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
26	27	28	29	30	31	01 V,L,T,C
02	03	04 V,L,T,C	05 V,L,C	06	07	08
09	10	11	12	13	14	15
16	17	18	19	20	21	22 C
23	24	25	26	27	28	29
30	01					

2019 October

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
30	01	02	03	04	05	06
07	08	09	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31	01	02	03
04	05					

2019 November

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
28	29	30	31	01	02	03
04	05	06	07	08	09	10
11 V	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	01
02	03					

Note: :Inter Tropical Convergence Zone (ITCZ) and Low Pressure
: Tropical Storm

V: Viet Nam L: Lao PDR
C: Cambodia T: Thailand

5. Special flash flood events in the LMB during flood season 2019.

5.1 Flash flood event on 19th June 2019 in the Northern part of Viet Nam, caused by ITCZ

5.1.1 Weather condition from June 14th – 20th June 2019

The southwest monsoon which prevailed over the Andaman Sea and Thailand was strong during the middle of the period. In addition, the monsoon trough lay across upper northern and upper northeastern parts on the first day of the period after that it moved northward to lie across Myanmar, Laos and upper Vietnam on 18 and 19 Jun. Associated with the low pressure cell covered upper Vietnam on 16 Jun. These conditions caused rainfall over upper Viet Nam mainly during the beginning and the middle of the period while southern part received rainfall (Figure 5.1-1)

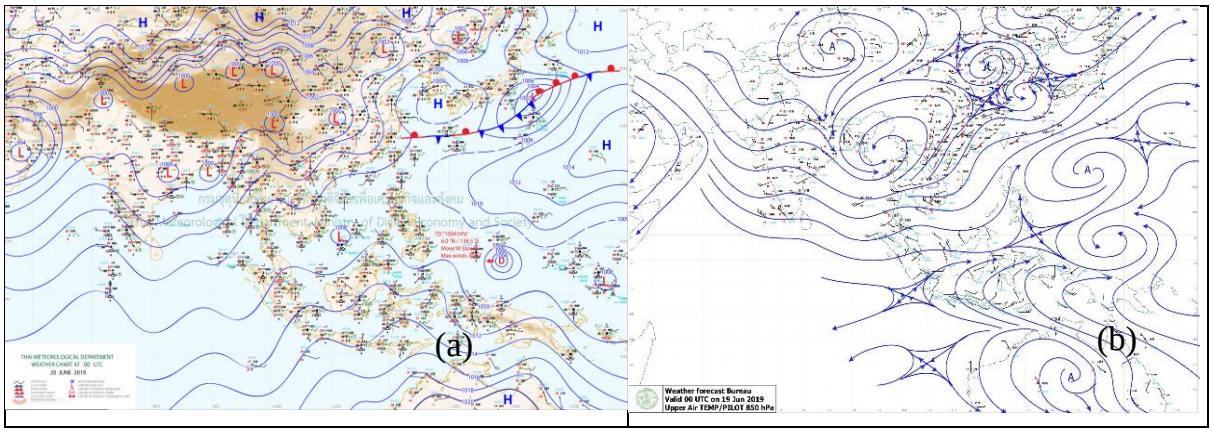
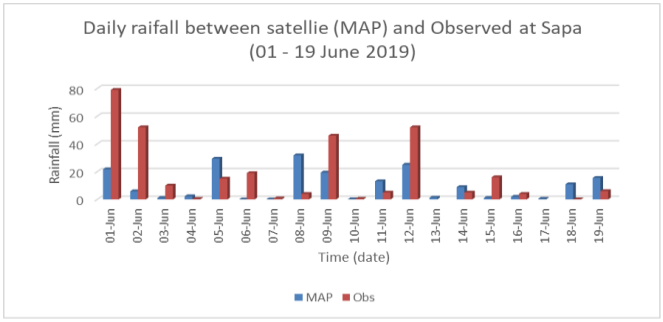
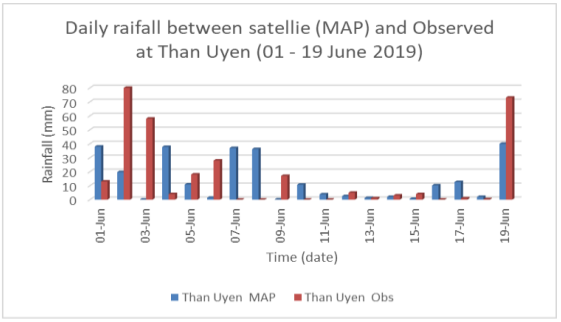


Figure 5.1-1: Weather condition map on 19 June 2019: (a) Weather map on and (b) Upper Air TEMP/Plot 850 (source: TMD, Thailand)

5.1.2 Heavy rainfall from 01st to 18th June 2019

During period time, the weather was influenced by ITCZ, trough of low pressure and moderate Southwest monsoon in the Mekong Region. These phenomena caused not much rainfall for LMB but caused heavy rain in the norther parts of Viet Nam; The daily rainfall was recorded at Lao Cai station (located in Lao Cai province) on 1 June 2019 was 150 mm and total rainfall from 01st to 18th 2019 at this location was about 300 mm. Besides, the heavy and moderate rain also occurred at others location closely with Lao Cai station, such as the total rainfall from 01 – 18 June 2019 at Sapa 314 mm, at Than Uyen 100 mm (figure 5.1-2 and figure 5.1-3).





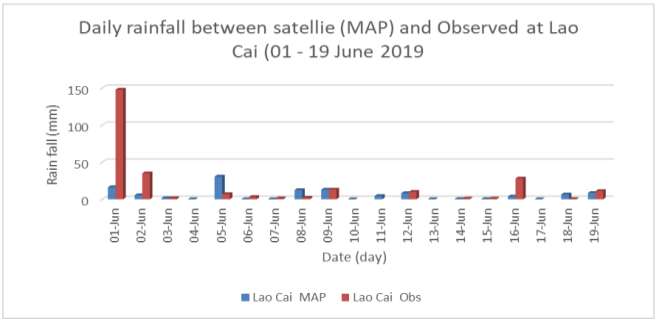


Figure 5.1-2: Comparison daily rainfall between MAP and Observed at some stations in Northern Viet Nam

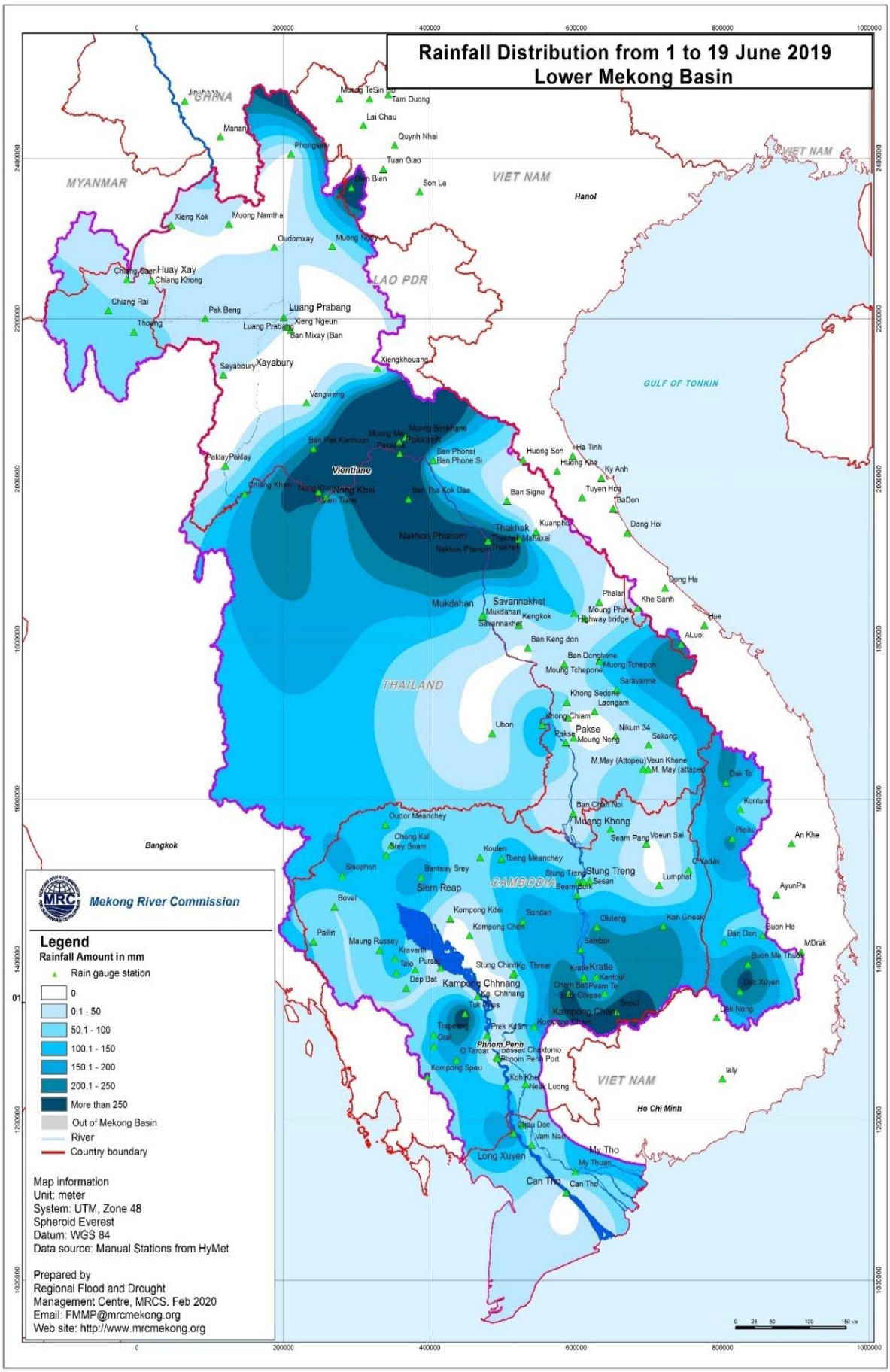


Figure 5.1-3: Rainfall distribution in LMB from 1st –19th June 2019.

5.1.3 Flash flood in Northern part of Viet Nam on 19th June 2019.

From analyzing the system's products while making flash flood guidance from MRCFFGS and based on actual measurements available in RFDMC (see figure 5.1-4). RFDMC made decision to submit the warning flash flood guidance for 1,3, and 6 hours as shown in the table 5.1-1.

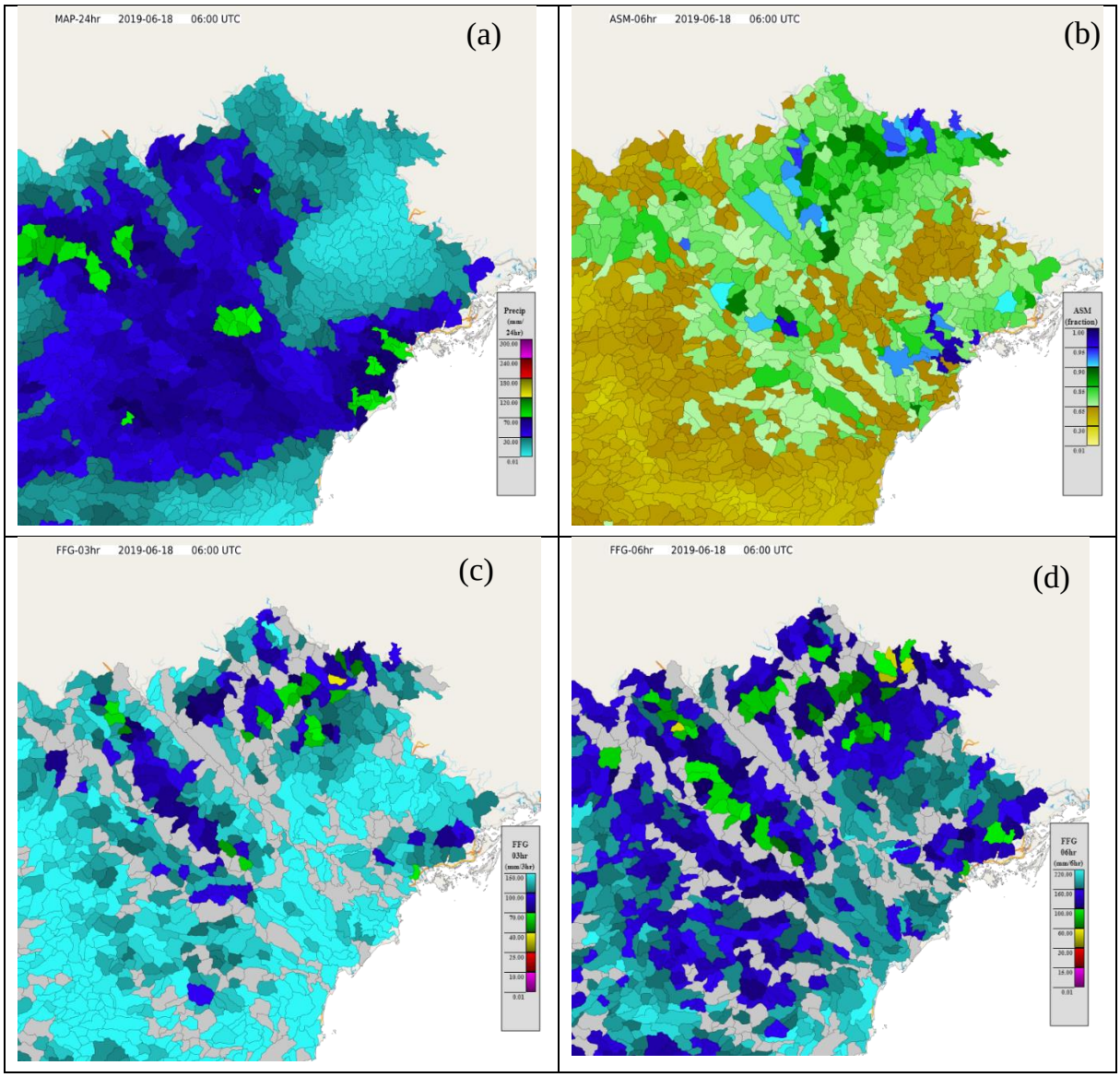


Figure 5.1-4: MRCFFGS's Product (a) MAP 24h pervious and (b) ASM 06h pervious, (c) FFG 03h and (d) FFG 06h on 18th June 2019 at 06:00 UTC (Local time 13: 00 PM)

Table 5.1-1: Flash flood guidance detected by MRCFFG system in Viet Nam on 24th June 2018 at 00 UTC (07: 00 AM Local time)

Date of FFG products	18/06/2019 00:00	UTC time						
1hour Flash Flood Guidance in Vietnam			3hours Flash Flood Guidance in Vietnam			6hours Flash Flood Guidance in Vietnam		
Provinces	Districts	FFG value	Provinces	Districts	FFG Value	Provinces	Districts	FFG Value
			Cao Bang	Hoa An	39.87	Lam Dong	Lam Ha	57.46
			Cao Bang	Nguyen Binh	34.27	Cao Bang	Hoa An	49.22
			Tuyen Quang	Chiem Hoa	38.14	Cao Bang	Hoa An	49.21
						Cao Bang	Nguyen Binh	42.59
						Lao Cai	Than Uyen	49.64
						Tuyen Quang	Chiem Hoa	48.62
						Bac Kan	Ba Be	56.96
						Tuyen Quang	Na Hang	57.56
						Tuyen Quang	Ham Yen	58.58

5.1.4 Conclusions

- During the period 14th – 19th June 2019, the strong ITCZ operated in the Mekong Region, it caused heavy rain at Norther parts of Viet Nam.
- The products of MRCFFGS such as Mean Areal Precipitation (MAP), Average Soil Moisture (ASM) which were detected under-estimated with observed data. However, RFMMC's forecaster analyzed the conditions weather and coordinated with LAs to summit bulletin with warning flash flood risk at those regionals.

5.2 Flash flood events on 03rd – 05th July 2019 in Viet Nam and Lao PDR, caused by typhoon "MUN"

5.2.1 Weather condition from 03rd – 09th July 2019

During the week of 03rd to 09th July 2019, there were stated that some tropical cyclones may develop at the western side of the northern Pacific Ocean and move pass the Philippines toward the South China Sea. Then, they may move northwesterly pass the Gulf of Tonkin and influence the Southwest Monsoon prevailing over Thailand and the Gulf of Thailand to strengthen. This influences the prevailing Southwest Monsoon over in the Mekong Region. Figures 5.2-1 and figure 5.2-2 present the weather map for 03rd July and 09th July 2019.

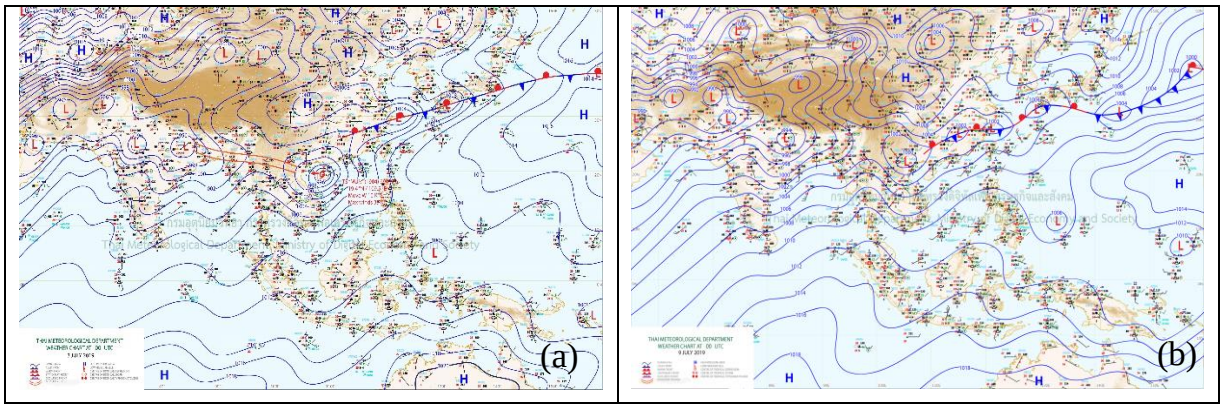


Figure 5.2-1: Weather map for (a) 03rd July 2019 and (b) 09th July 2019

Source: TMD, Thailand

On July 1, an area of low pressure organized into a tropical depression formed in the Pacific Ocean, near Hainan and the Paracel Islands. The system gradually organized while drifting eastward. On the next day, the tropical depression strengthened into a tropical storm, and the Japan Meteorological Agency (JMA) named the storm MUN. Later that day, Tropical Storm Mun made landfall on the island of Hainan. However, the Joint Typhoon Warning Center (JTWC) still recognized Mun as a monsoon depression and didn't upgrade it into a tropical cyclone for another day. Late on July 3, after the storm had nearly crossed the Gulf of Tonkin to the coast of Vietnam, the JTWC upgraded

the storm to tropical storm status and initiated advisories on the system, stating that MUN had organized enough to be considered a tropical cyclone. Between 4:30–5:00 a.m. ICT on July 4 (21:30–22:00 UTC on July 3), MUN made landfall in Thai Binh Province in northern Vietnam. The track of MUN is shown in figure 5.2-2.

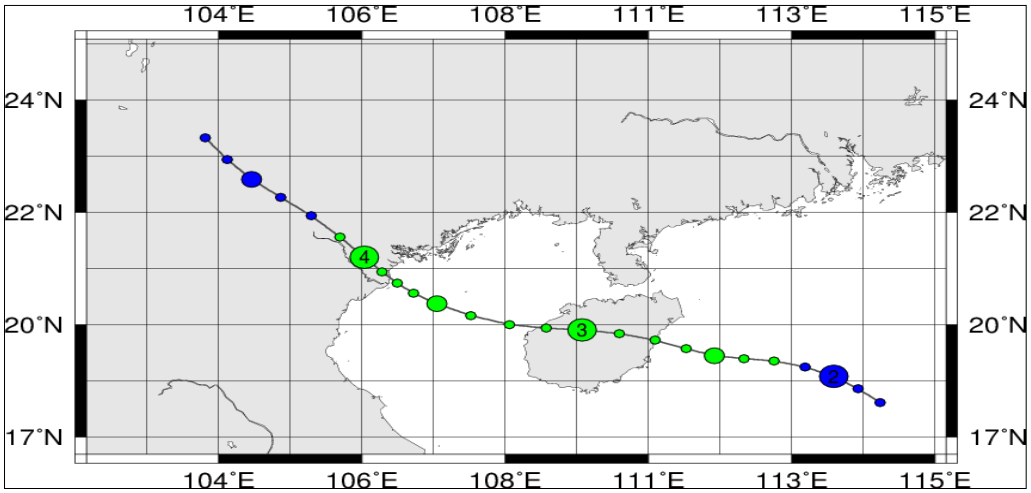


Figure 5.2-2: The tracks of tropical typhoon "MUN"

5.2.2 Heavy rainfall during 03rd – 09th July 2019

During this period with the weather conditions as mentioned above heavy rain in the Northern parts of LMB by the MUN. Consequently, there was heavy rainfall appeared between Luang Prabang and Nakhon Phanom catchments of LMB (see figure 5.2-3) and also regions at North Centre Parts of Viet Nam (Nghe An, Ha Tinh provinces of Viet Nam), including some areas at transboundary of Lao PDR (Boli-kham-xay, Kham-mua-ne and Xieng-Khoang).

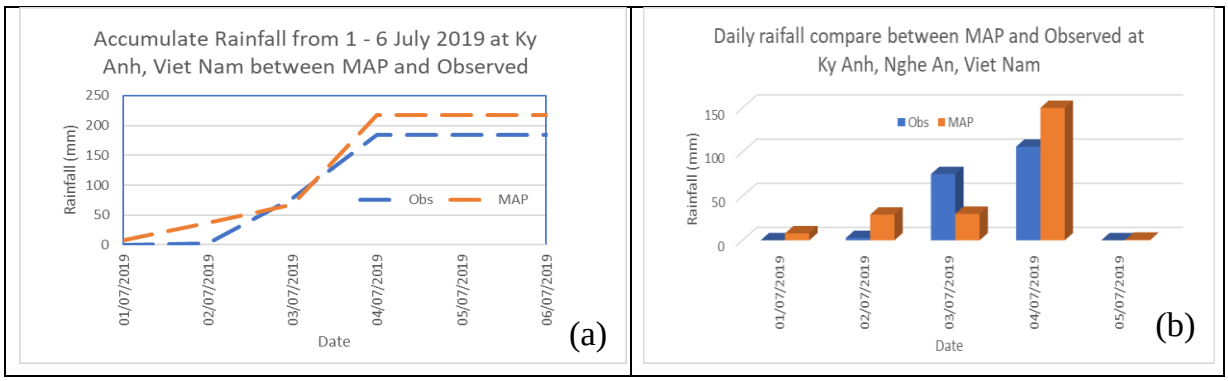


Figure 5.2-3: comparison rainfall between MAP and Observed at Ky Anh station, Nghe An province of Viet Nam during period 1-6 July 2019: (a) Accumulate rainfall; (b) Daily rainfall

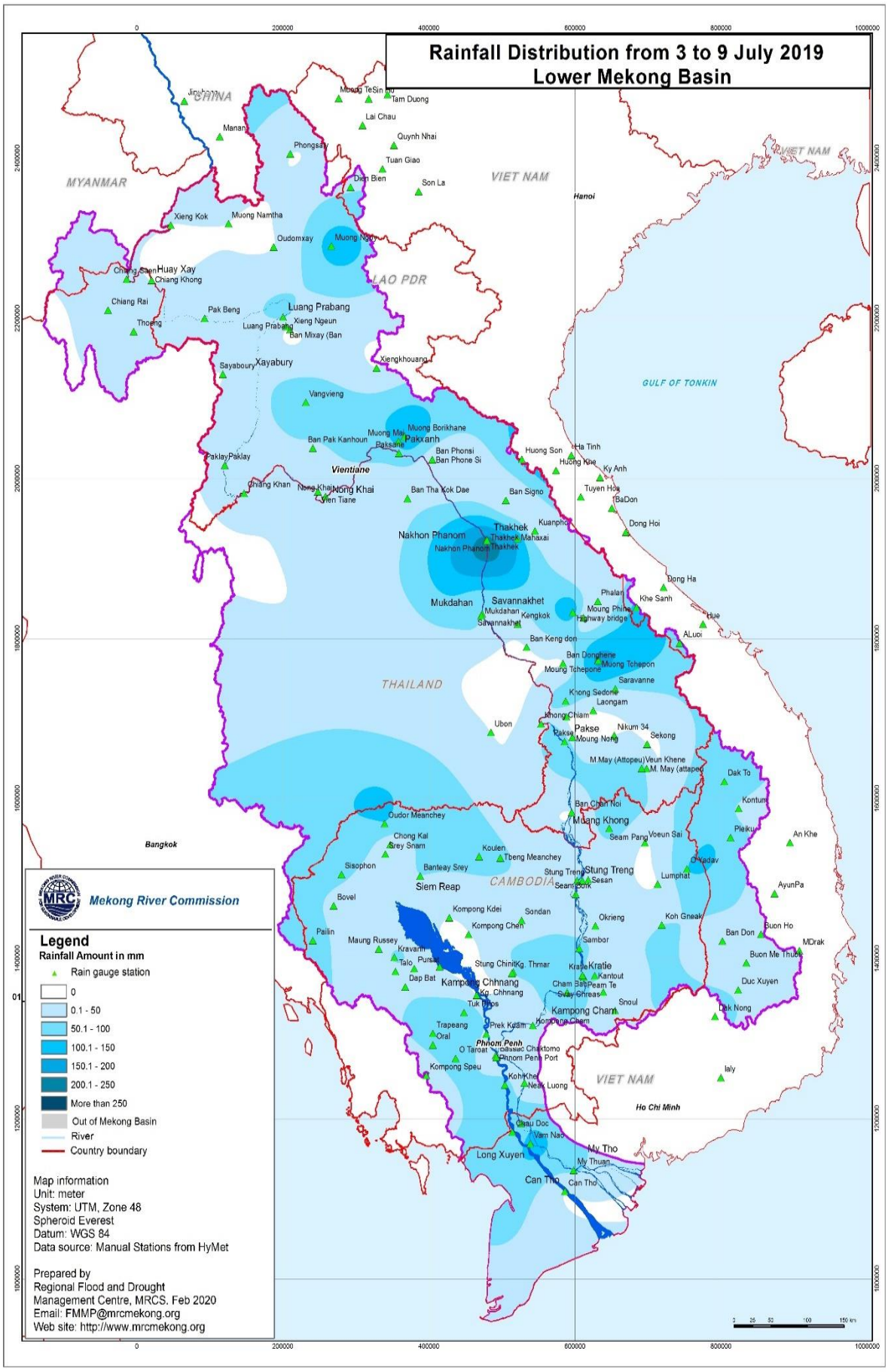


Figure 5.2-4: Rainfall distribution during 03rd – 09th July 2019 in LBM

5.2.3 Flash Flood in Mekong Region on 03rd - 09th July 2019

During this time, the MRCFFGS detected the rainfall, soil moisture quite correct at some areas of Northern – Central Viet Nam including some areas at boundary of Lao PDR. There were some flash flood events occurred during that period at those areas (see figure 5.2-5 and table 5.2-1 and table 5.2-2)

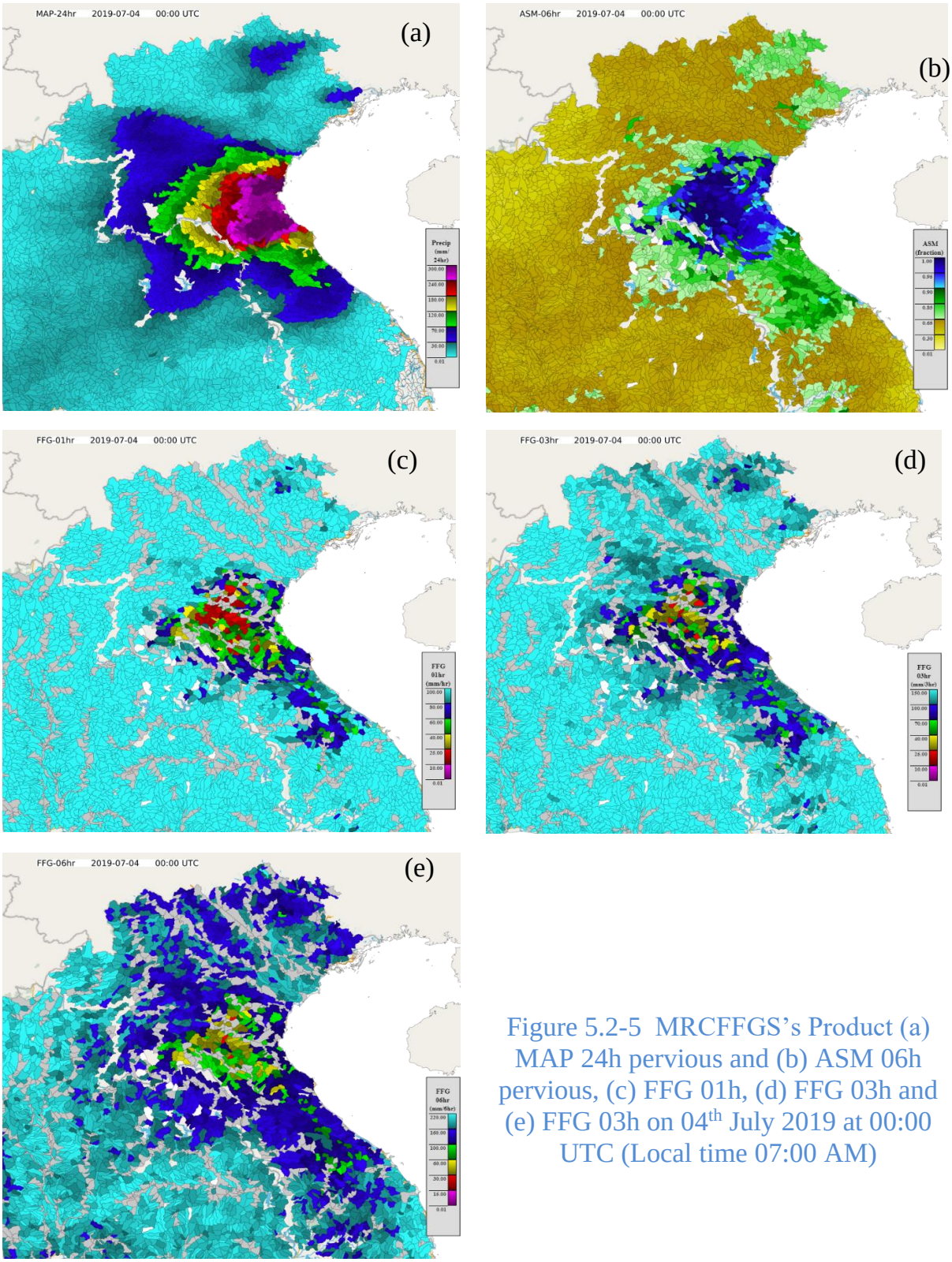


Figure 5.2-5 MRCFFGS's Product (a) MAP 24h pervious and (b) ASM 06h pervious, (c) FFG 01h, (d) FFG 03h and (e) FFG 03h on 04th July 2019 at 00:00 UTC (Local time 07:00 AM)

Table 5.2-1: Flash flood guidance detected by MRCFFG system in Viet Nam on 04th July 2019 at 00 UTC (07: 00 AM Local time)

Date of FFG products	04/07/2019 00:00 UTC time							
1hour Flash Flood Guidance in Vietnam			3hours Flash Flood Guidance in Vietnam			6hours Flash Flood Guidance in Vietnam		
Provinces	Districts	FFG value	Provinces	Districts	FFG Value	Provinces	Districts	FFG Value
Quang Binh	Minh Hoa	18.92	Quang Binh	Minh Hoa	27.57	Quang Tri	Huong Hoa	56.19
Ha Tinh	Huong Son	14.2	Ha Tinh	Huong Son	22.28	Quang Binh	Minh Hoa	37.4
Nghe An	Con Cuong	16.25	Nghe An	Con Cuong	24.27	Ha Tinh	Huong Son	31.68
Ha Tinh	Huong Khe	20.2	Ha Tinh	Huong Khe	29.75	Quang Tri	Da Krong	58.48
Nghe An	Anh Son	20.23	Nghe An	Anh Son	32.3	Thua Thien Hue	Phong Dien	59.58
						Nghe An	Con Cuong	33.29
						Ha Tinh	Huong Khe	40.65
						Nghe An	Anh Son	46.8

Table 5.2-2: Flash flood guidance detected by MRCFFG system in Lao PDR on 04th July 2019 at 00 UTC (07: 00 AM Local time)

Date of FFG produc	04/07/2019 00:00	UTC time						
1hour Flash Flood Guidance in Lao			3hours Flash Flood Guidance in Lao			6hours Flash Flood Guidance in Lao		
Provinces	Districts	FFG value	Provinces	Districts	FFG value	Provinces	Districts	FFG value
Bolikhamxay	Viengthon	19.74	Bolikhamxay	Viengthon	29.08	Saravane	Ta oi	51.11
Bolikhamxay	Viengthon	24.37	Bolikhamxay	Viengthon	39.92	Bolikhamxay	Viengthon	51.92
Bolikhamxay	Viengthon	22.46	Bolikhamxay	Viengthon	33.67	Bolikhamxay	Viengthon	39.47
Bolikhamxay	Viengthon	17.07	Bolikhamxay	Viengthon	31.6	Bolikhamxay	Viengthon	51.42
Bolikhamxay	Khamkheut	18.01	Bolikhamxay	Viengthon	24.6	Bolikhamxay	Viengthon	44.13
Bolikhamxay	Khamkheut	16.45	Bolikhamxay	Khamkheut	26.85	Bolikhamxay	Viengthon	41.74
Khammuane	Hinboon	17.44	Bolikhamxay	Khamkheut	37.16	Bolikhamxay	Viengthon	33.54
Khammuane	Hinboon	18.17	Bolikhamxay	Khamkheut	34.28	Bolikhamxay	Khamkheut	36.8
Bolikhamxay	Viengthon	19.12	Khammuane	Nakai	35.08	Bolikhamxay	Khamkheut	58.82
Bolikhamxay	Viengthon	18.74	Bolikhamxay	Khamkheut	25.62	Bolikhamxay	Khamkheut	48.57
Bolikhamxay	Khamkheut	23.43	Khammuane	Hinboon	25.65	Bolikhamxay	Khamkheut	44.9
Khammuane	Nakai	22.72	Khammuane	Hinboon	26.24	Khammuane	Nakai	45.92
Bolikhamxay	Khamkheut	14.15	Bolikhamxay	Viengthon	29.22	Bolikhamxay	Khamkheut	36.15
Bolikhamxay	Khamkheut	14.95	Bolikhamxay	Viengthon	29.62	Bolikhamxay	Khamkheut	59.64
			Bolikhamxay	Khamkheut	35.94	Khammuane	Hinboon	34.56
			Khammuane	Nakai	33.78	Khammuane	Hinboon	34.64
			Bolikhamxay	Khamkheut	22.37	Xiengkhuang	Morkmay	58.06
			Bolikhamxay	Khamkheut	23.73	Bolikhamxay	Viengthon	54.31
						Bolikhamxay	Viengthon	40.79
						Bolikhamxay	Viengthon	42.86
						Bolikhamxay	Khamkheut	51.04
						Khammuane	Nakai	46.76
						Bolikhamxay	Khamkheut	31.89
						Bolikhamxay	Khamkheut	34.1

5.2.4 Conclusions

- The circulation after MUN tropical storm and the high pressure of depression are the causes of heavy rain in North Central parts of Viet Nam and Lao PDR, therefore some flash flood events have appeared at those areas
- The MRCFFGS products correctly detected several locations that are likely to occur the flash floods as in the timely and spatial vis compared with information on the website as well as coordinate with MCs. However, the satellite rainfall estimate (MAP) products of MRCFFGS was a little overestimating with the observer data in some locations in Mekong region (Figure 5.2-3)

5.3 Flash flood events from 25th July to 05th August 2019 in the Lao PDR, Viet Nam and Cambodia, caused by Tropical storm "WIPHA" and other phenomena

5.3.1 Weather condition during 25th July – 05th August 2019

Tropical storm situation during period 20th July to 3rd August 2019 in the Ocean Pacific.

Circulation tropical NARI: Circulation tropical NARI: On July 21, the JTWC started tracking an area of low pressure associated with the remnant of Tropical Depression Goring for the potential formation of a tropical cyclone. Under favorable conditions, the system organized itself in the next several days. At 00:00 UTC on July 24, it developed into a tropical depression to the west of the Bonin Islands. The storm gradually became more organized while moving North Northwestward. Early on July 25, the JTWC initiated advisories on the storm and gave it the identification "07W". Early on July 26, the tropical depression strengthened into a tropical storm, and the JMA named it NARI while it moved northwards. The storm approached southern Japan and as it moved inland, it weakened into a tropical depression. Several hours later, it degenerated into a remnant low. Thus, the JTWC and JMA issued their final advisories on the system. Although this tropical storm did not make landfall to Viet Nam its circulation made other weather phenomena such as tropical depressions more active in the Mekong region during the period of 20th to 25th July 2019.

Landfall of tropical storm "WIPHA": On July 30, a tropical depression formed in the East Sea near Paracel Islands of Viet Nam. On the next day, it strengthened into a tropical storm, and JMA named it WIPHA. On Aug 2, 2019, a Tropical Storm Warning was in effect for coastal areas in northeastern Vietnam. The Vietnam National Center for Hydro-Meteorological Forecasting (NCHMF) expects WIPHA to track along the southern China coast and move into Vietnam tracking to the southwest. NCHMF expects WIPHA's center to pass just south of Hanoi. At 11 a.m. EDT (1500 UTC) on Aug 2, WIPHA had maximum sustained winds near 35 knots (40 mph/64 kph). It was centered near 21.6 degrees north latitude and 108.5 degrees east longitude, about 150 nautical miles east-northeast of Hanoi, Vietnam. WIPHA was moving to the west and then made landfall in Vietnam on August 2 and dissipated fully the next day (figure 5.3-1). The circulation of WIPHA caused heavy rains in some areas from the North to the North Central Viet Nam in the early days of August, including some areas of the Mekong region.

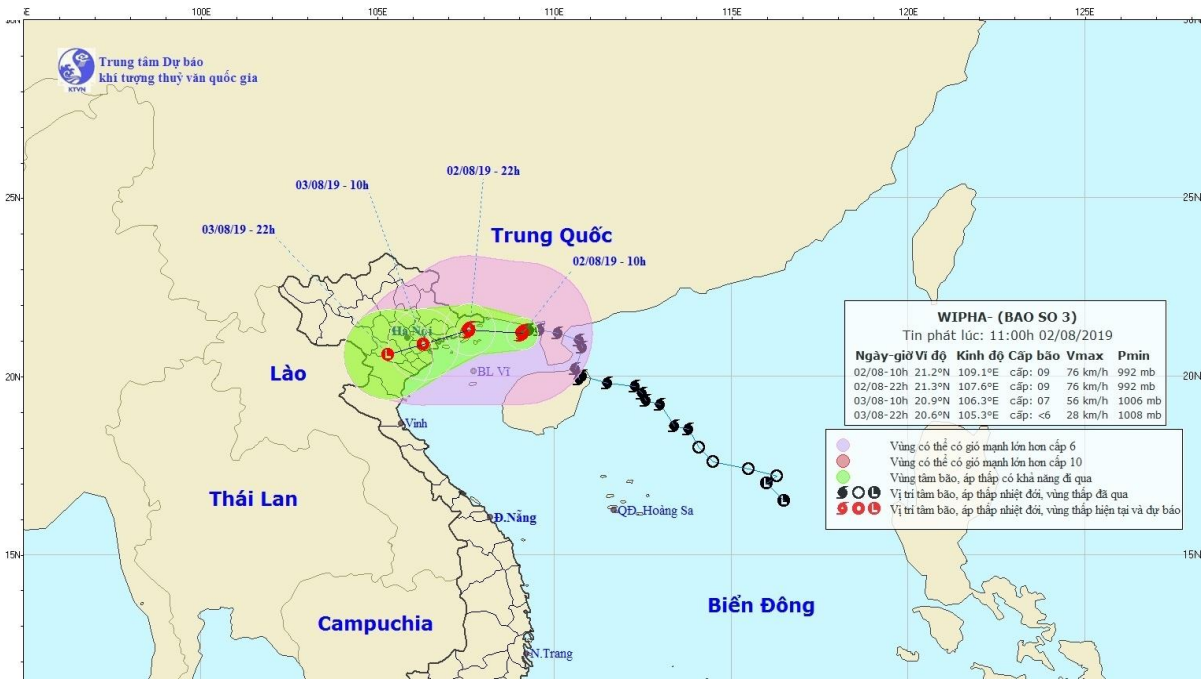


Figure 5.3-1 The track of tropical storm WIPHA

(Source: NCHMF)

Southwest Mosoon: During period 20th – 25th July 2019, the active southwest monsoon prevailed over the Andaman Sea, the southern part and the Gulf of Thailand almost the week causing abundant rainfall in the southern part almost the week especially along the west coast that experienced heavy to very heavy rainfall in several areas. In upper Thailand, there was less rainfall except for plentiful rain that was observed along the lower coast of the eastern part. Moreover, at the same the low pressure was moved from the north part to the middle part of LMB, it is caused to bring heavy rain in these areas. (see figure 5.3-2).

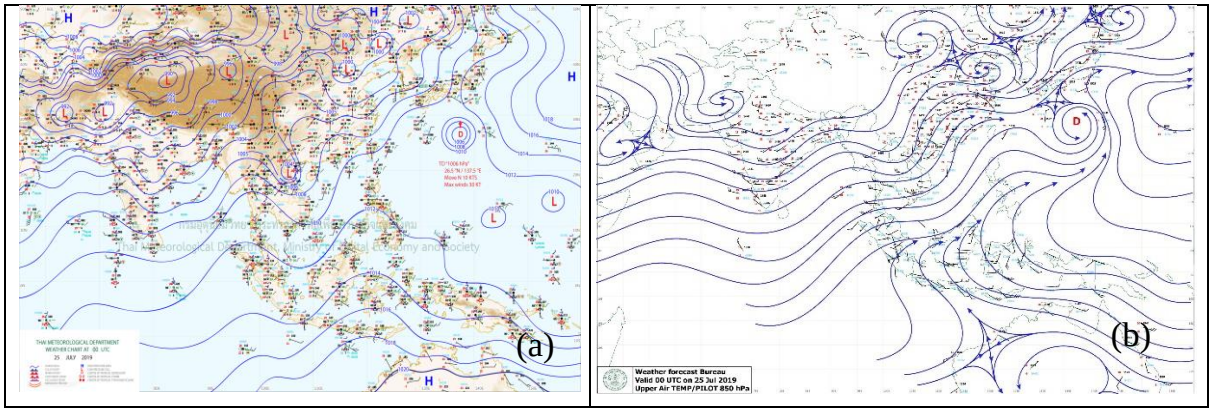


Figure 5.3-2: (a) Weather map; (b) Upper Air Temp/Pilot 850 hPa on 25th July 2019 (source: TMD, Thailand)

5.3.2 Heavy rain during 25th July to 01st August 2019

The weather during period was scattered thundershowers with moderate rain of the Southwest monsoon and tropical storm "MUN". Consequently, there was moderate

rainfall and heavy rain covered from upper part of upper Vientiane and Paksane, varied from 150 mm to 200 mm. It was also happened from Pakse down to 3S area in Cambodia, showed varied more 200 - 250 mm (figure 5.3-4).

Figure 5.3-3 shown that rainfall was detected quite well by MRCFFGS during the period 25 July to 5 August 2019 at some areas in the Mekong Region, where have flash flood events occurred.

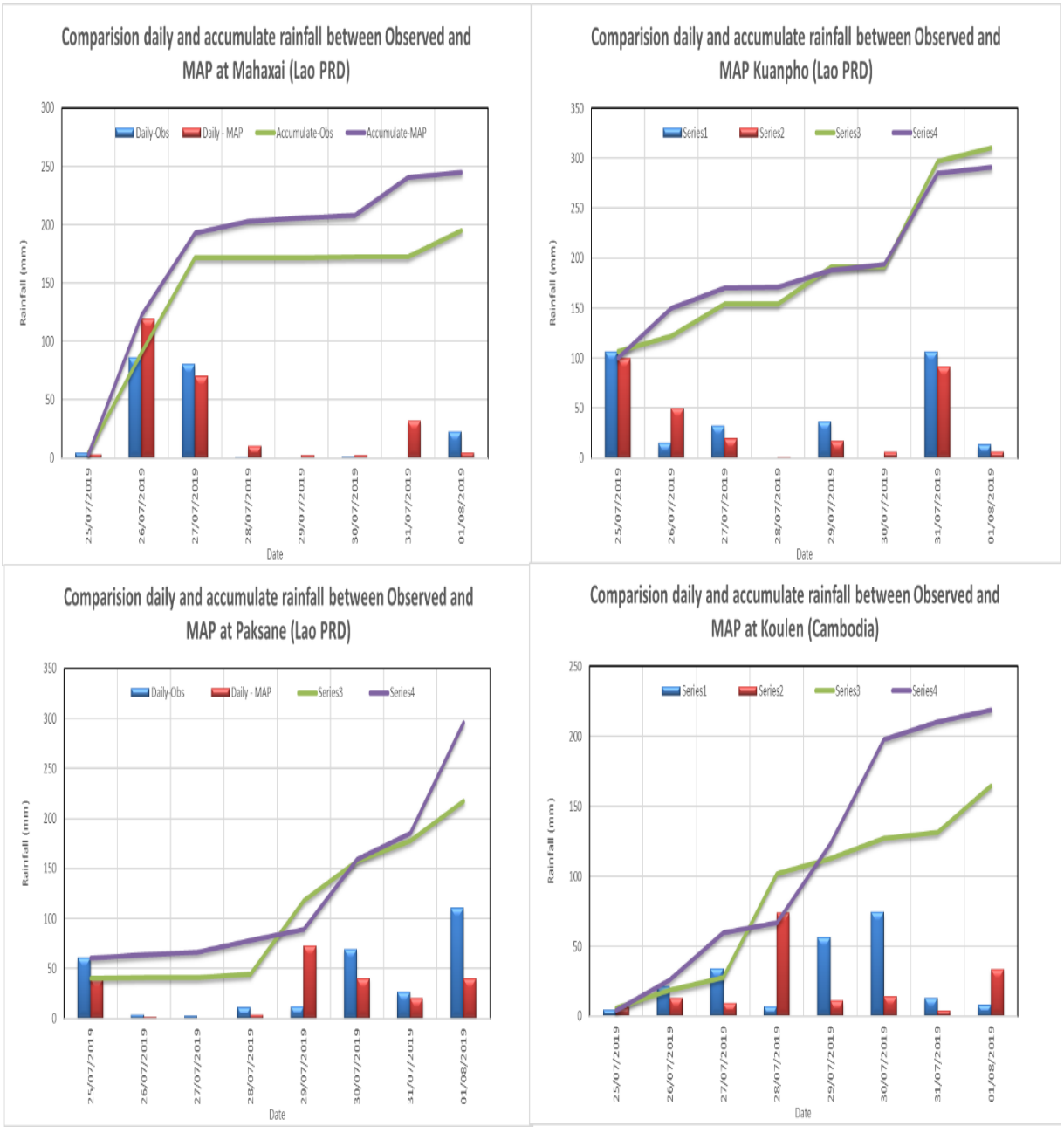


Figure 5.3-3: Comparison daily and accumulate rainfall between observed and Mean Areal Precipitation at some location in LMB (from 25th July to 05th August 2019)

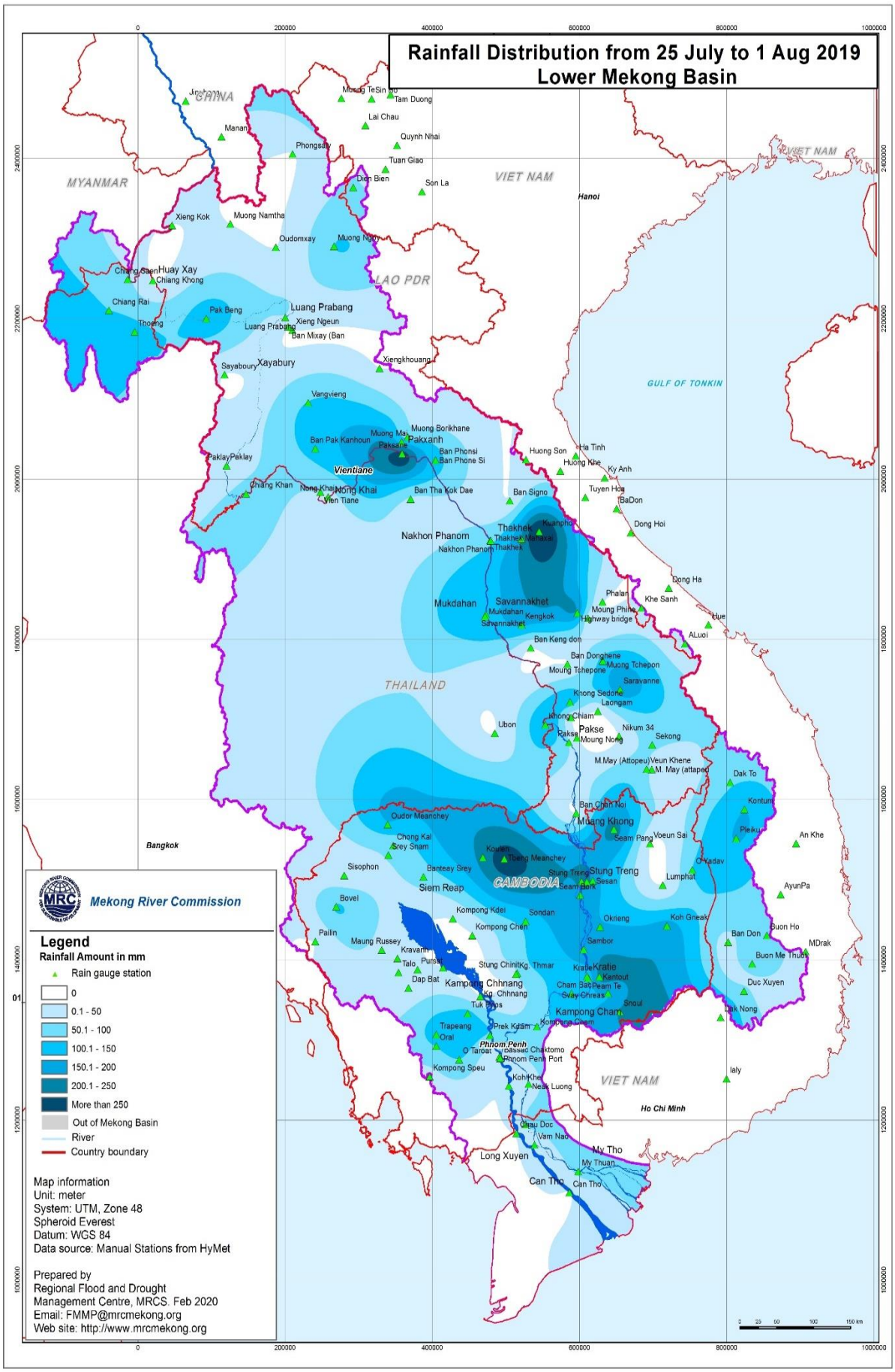


Figure 5.3-4: Rainfall distribution during 25th July – 01st August 2019 in LBM

5.3.3 Flash flood events in Lao PDR, Cambodia on 30th July 2019, in Viet Nam on 05th August 2019.

Based on the conditions of the weather in the Mekong region as mentioned above and analyzing the products of MRCFFGS, on 30th July 2019 some flash flood event occurred in some areas in LMB were detected by MRCFFGS. Figure 5.3-5, table 5.3-1, table 5.3-2, table 5.3-3 presents MRCFFGS' products to detect the flash flood events on 30th July 2019 in Lao PDR, Cambodia, and Viet Nam on 05th August and figure 5.3-6 present a media report about flash flood occurred in Cambodia.

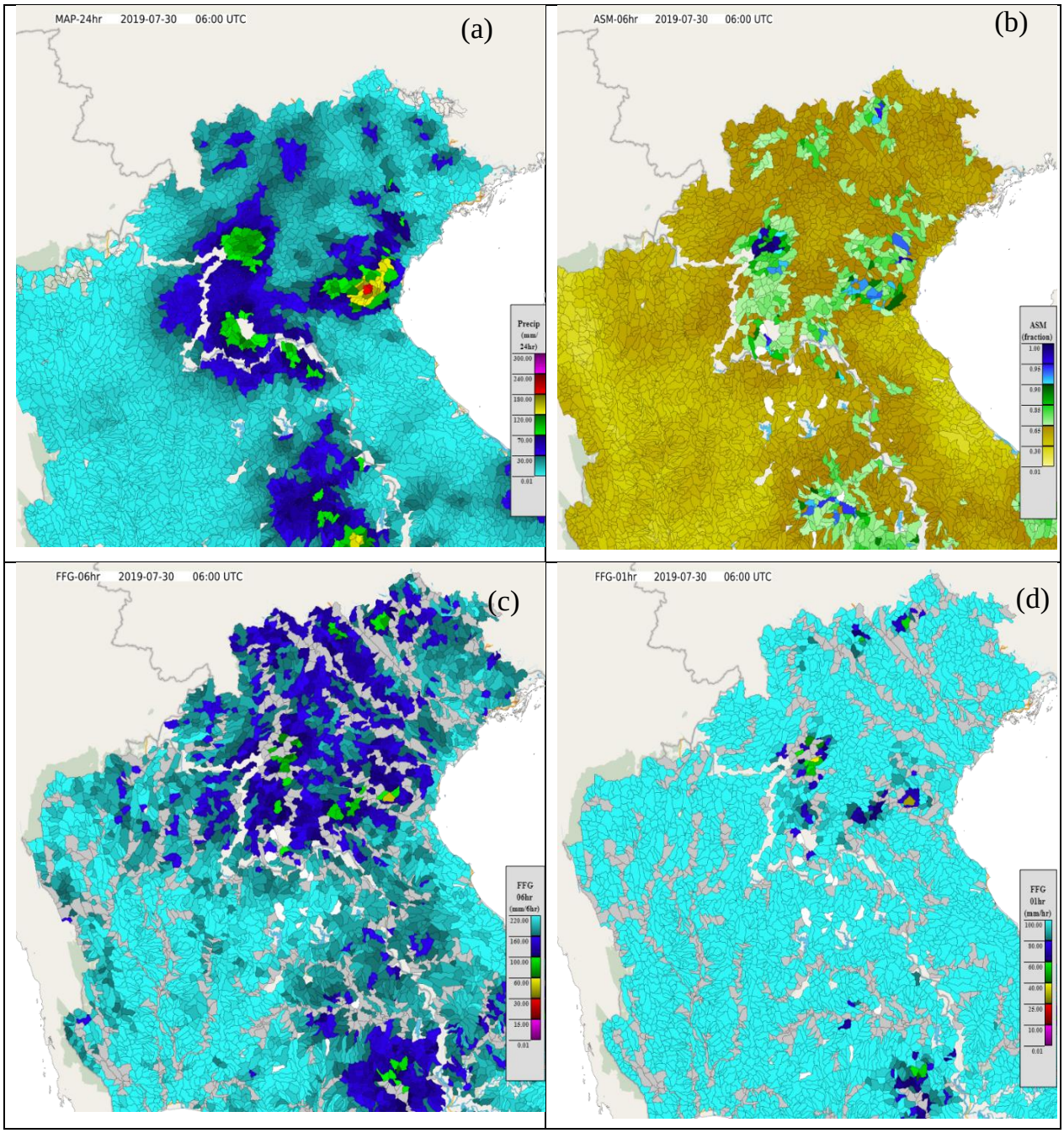


Figure 5.3-5: MRCFFGS's Product (a) MAP 24h pervious and (b) ASM 06h pervious, (c) FFG 6h and (c) FFG 01 h on 30th July 2019 at 06:00 UTC (local time 13:00 PM)

Figure 5.3-6: Media of Flash Flood in Cambodia on 30th July 2019

Table 5.3-1: Flash flood guidance detected by MRCFFG system in Lao PDR on 30th July 2019 at 00 UTC (07: 00 AM Local time)

Date of FFG produc	30/07/2019 00:00	UTC time						
1hour Flash Flood Guidance in Lao			3hours Flash Flood Guidance in Lao			6hours Flash Flood Guidance in Lao		
Provinces	Districts	FFG value	Provinces	Districts	FFG value	Provinces	Districts	FFG value
			Xaysomboun	Thathom	39.87	Xaysomboun	Thathom	49.33
			Xiengkhuang	Morkmay	33.59	Xaysomboun	Thathom	51.27
						Xiengkhuang	Morkmay	57.56
						Xiengkhuang	Morkmay	42.84
						Xiengkhuang	Morkmay	56.54

Table 5.3-2: Flash flood guidance detected by MRCFFG system in Cambodia on 30th July 2019 at 00 UTC (07: 00 AM Local time)

Date of FFG products	30/07/2019 00:00	UTC time						
1hour Flash Flood Guidance in Cambodia			3hours Flash Flood Guidance in Cambodia			6hours Flash Flood Guidance in Cambodia		
Provinces	Districts	FFG value	Provinces	Districts	FFG value	Provinces	Districts	FFG value
Preah Vihear	Choam Khsant	22.12	Preah Vihe	Choam Khsar	31.02	Preah Vihear	Choam Khsant	40.89

Table 5.3-3: Flash flood guidance detected by MRCFFG system in Viet Nam on 05th August 2019 at 00 UTC (07: 00 AM Local time)

	A	B	C	D	E	F	G	H	I	J	K
1	Date of FFG products	05/08/2019 06:00	UTC time								
2	1hour Flash Flood Guidance in Vietnam				3hours Flash Flood Guidance in Vietnam				6hours Flash Flood Guidance in Vietnam		
3	Provinces	Districts	FFG value		Provinces	Districts	FFG Value		Provinces	Districts	FFG Value
4	Thanh Hoa	Muong Lat	18.45		Hoa Binh	Mai Chau	38.4		Son La	Moc Chau	54.55
5					Thanh Hoa	Quan Hoa	39.34		Hoa Binh	Mai Chau	48.37
6					Thanh Hoa	Muong Lat	25.16		Nghe An	Tuong Duong	52.45
7									Thanh Hoa	Muong Lat	32.83
8									Thanh Hoa	Quan Son	56.74
9									Nghe An	Que Phong	52.25
10											
11											

5.3.4 Conclusions

- The circulation after tropical NARI, WIPHA and Southwest Mosoon, those all are the causes of heavy rain in wide area Central of Mekong region including Viet Nam and Lao PDR in this period.
- In some areas in the mountain in the Mekong region, the soil moisture is saturated and combined add more the heavy rain at the same time, therefore these areas the flash flood has been appeared.
- The MRCFFGS correctly detected several locations that are likely to occur the flash floods.

5.4 Flash flood events on 30th August 2019 in MCs caused by PODUL

5.4.1 Weather condition during 29th August – 05th September 2019

The tropical storm "PODUL (1912)" in the upper South China Sea made landfall over Dong Hoi, Vietnam at 00.30 a.m. on 30 Aug. and passing through Laos before entering Thailand at Nakhon Phanom province at 05.30 a.m. It weakened into tropical depression at 09.00 a.m. while moving through Sakon Nakhon province and passing Udon Thani and Nong Bua Lamphu provinces to Loei and downgraded into active low-pressure cell at 09.00 p.m. on the same day. It covered lower northern part on the following day. In addition, the monsoon trough lay across the northern and upper northeastern parts toward the low pressure cell in Laos and Vietnam during the first half of the week and then moved southward to lie over the lower northern, upper central and northeastern part toward the mention tropical storm during the middle of the period (figure 5.4 -1) . It lay across the northern and upper northeastern parts toward the tropical depression in the upper South China Sea on the last day of the week. Besides, the active southwest monsoon prevailed over the Andaman Sea, Thailand, and the Gulf of Thailand throughout the week. These conditions caused abundant rainfall nationwide especially in the northern and northeastern part that experienced torrential rain causing flash flooding and landslide in some areas mainly during the second half of the week.

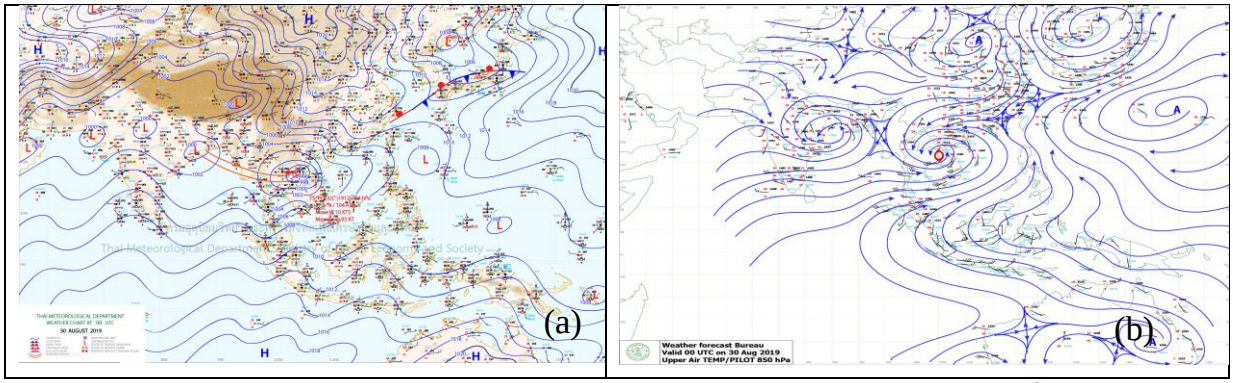


Figure 5.4 -1 (a) Weather map, (b) Upper Air TEMP/PILOT 850 hPa 0n 30th August 2019

Typhoon "PODUL": On August 25, the Japan Meteorological Agency began to track a tropical depression near Ifalik. On the next day, PAGASA named the storm Jenny, and the Joint Typhoon Warning Center designated the storm as 13W. On August 27, the system intensified to become a tropical storm, and was given the name PODUL. PODUL made landfall in Casiguran, Aurora at 10:40 p.m. PST (14:40 UTC). It then emerged over the East Sea and headed for Vietnam. PODUL then intensified a bit further, before making landfall there. On Aug 29, 2019 at 2 a.m. (0600 UTC), the PODUL had already started its landfall in central Vietnam and appeared somewhat elongated because northerly winds outside the storm are pushing clouds south of the center.

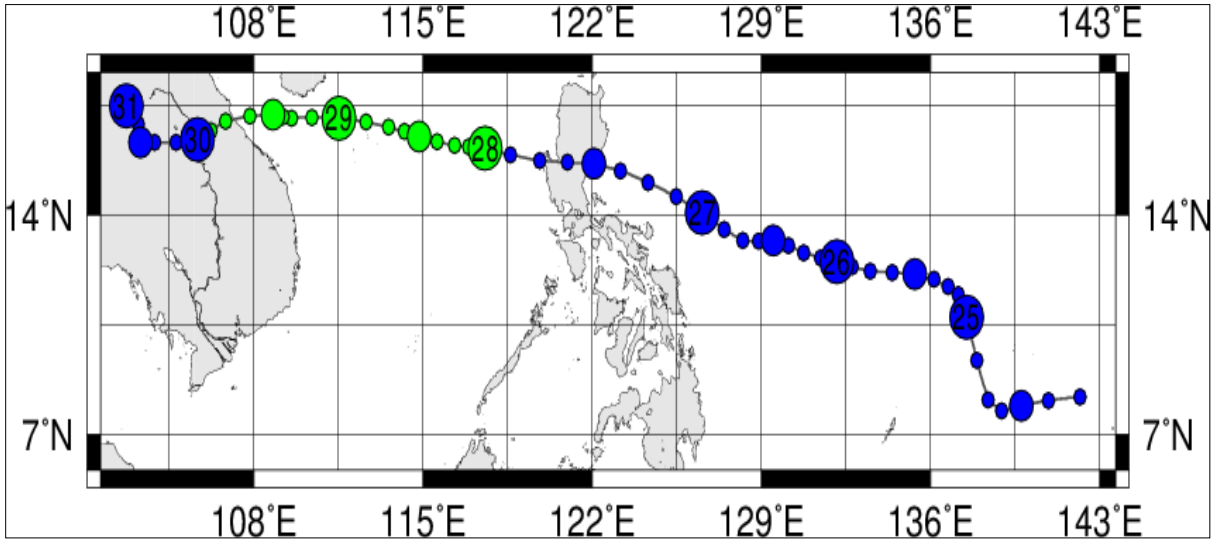


Figure 5.4-2: Track of typhoon PODUL

At 5 a.m. (0900 UTC) on Aug 29, Tropical storm PODUL was centered near 17.8 degrees north latitude and 108.3 degrees east longitude, about 108 nautical miles north of Da Nang, Vietnam. PODUL continued moving west and had maximum sustained winds 35 knots (40 mph/65 kph).

The Vietnam National Centre for Hydro-Meteorological Forecasting (NCHMF) is a governmental organization belonging Vietnam Meteorological Hydrological Administration (VMHA) with authority to issue forecasting/warning information for weather, climate, hydrology, water resource, marine weather (i.e. hydrometeorology) and provide hydro-meteorology services. NHCMF has issued a Tropical Storm Warning for central Vietnam with the approach of PODUL. Figure 5.4-2 presents the track of typhoon PODUL.

5.4.2 Heavy rain during 29th August to 05th September 2019

The weather of this period was brought heavy rainfall due to the Typical Cyclone PODUL and its tropical depression. Consequently, from 29th August 2019 to 05th September 2019,

there was very heavy rainfall covered from in the middle part of LMB, focused at varied daily rainfall from 100 mm to more than 250 mm as the figure 4.3.4-4 shows the accumulate rainfall distribution over in the Lower Mekong Basin from 29th Aug to 05th Sept 2019. The heavy rain demonstrated from Nakhon Phanon to Pakse in LBM and extent to tributaries at Northern part of Lao PDR, Central part of Viet Nam and South East part of Thailand.

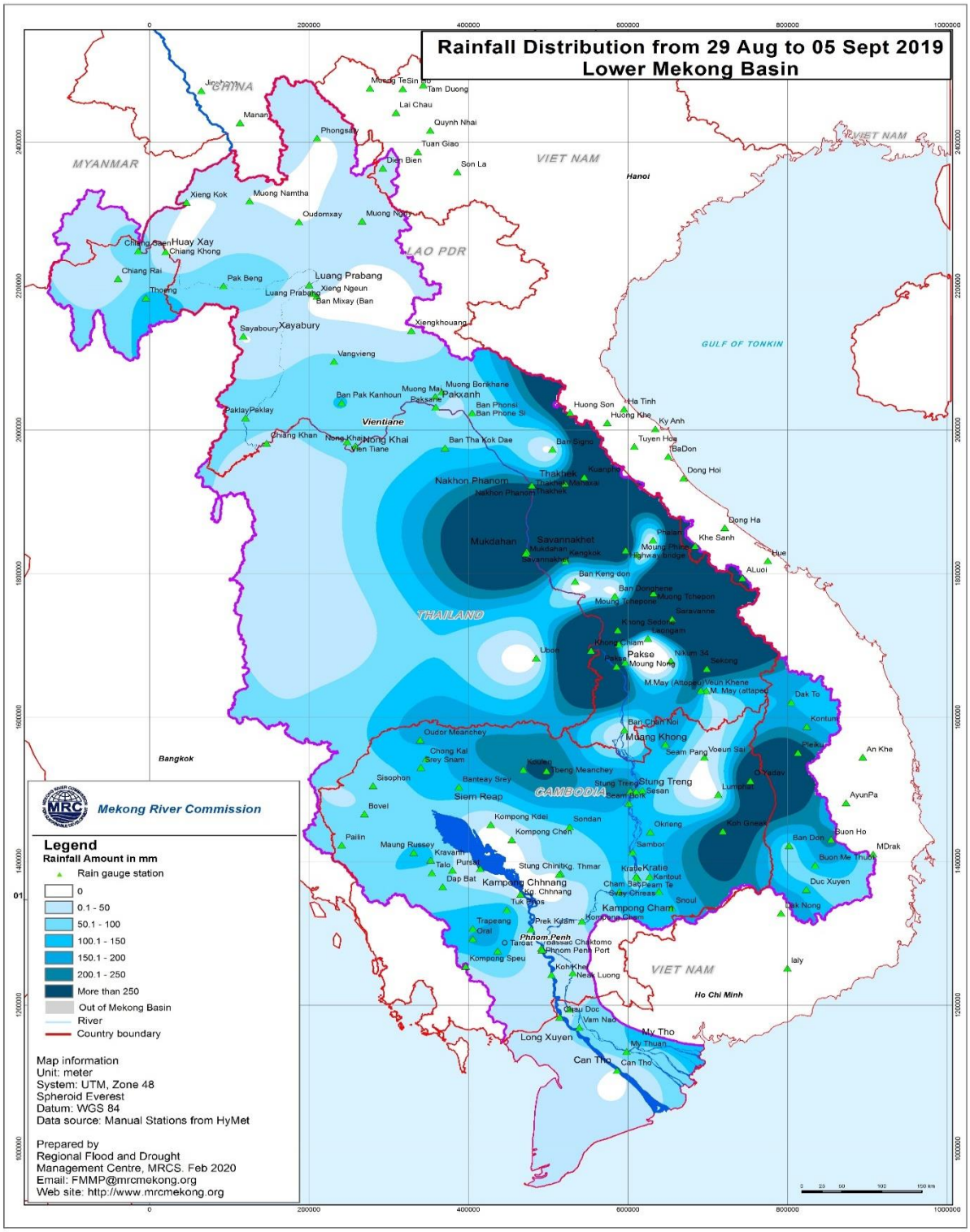


Figure 5.4-4 Rainfall distribution during 29th August – 05th September 2019 in LBM

5.4.3 Flash flood events during 30th August - 03rd September 2019 in the LMB

During period, the local heavy rains due to the meteorological factors as mentioned above, and base on the satellite product analysis, soil moisture previous 06 hours from MRCFFGS, the soil maybe has been saturated in some areas in the northern part Lao PDR, Central of Vietnam, Eastern part of Thailand, and Northern part of Cambodia (see figure 5.4-5). The products of FFG from MRCFFGS for the next 01, 03 and 06 hr products on 30th, 31st August and on 3rd September 2019 were awarded warning for LMB (Figure 5.4-6). Some of those detection results (including time and space) are also corrected with newspaper and actual the flash flood occurred in the Mekong region (tables: 5.4-1; 5.4-2; 5.4-3; 5.4-4; 5.4-5; 5.4-6).

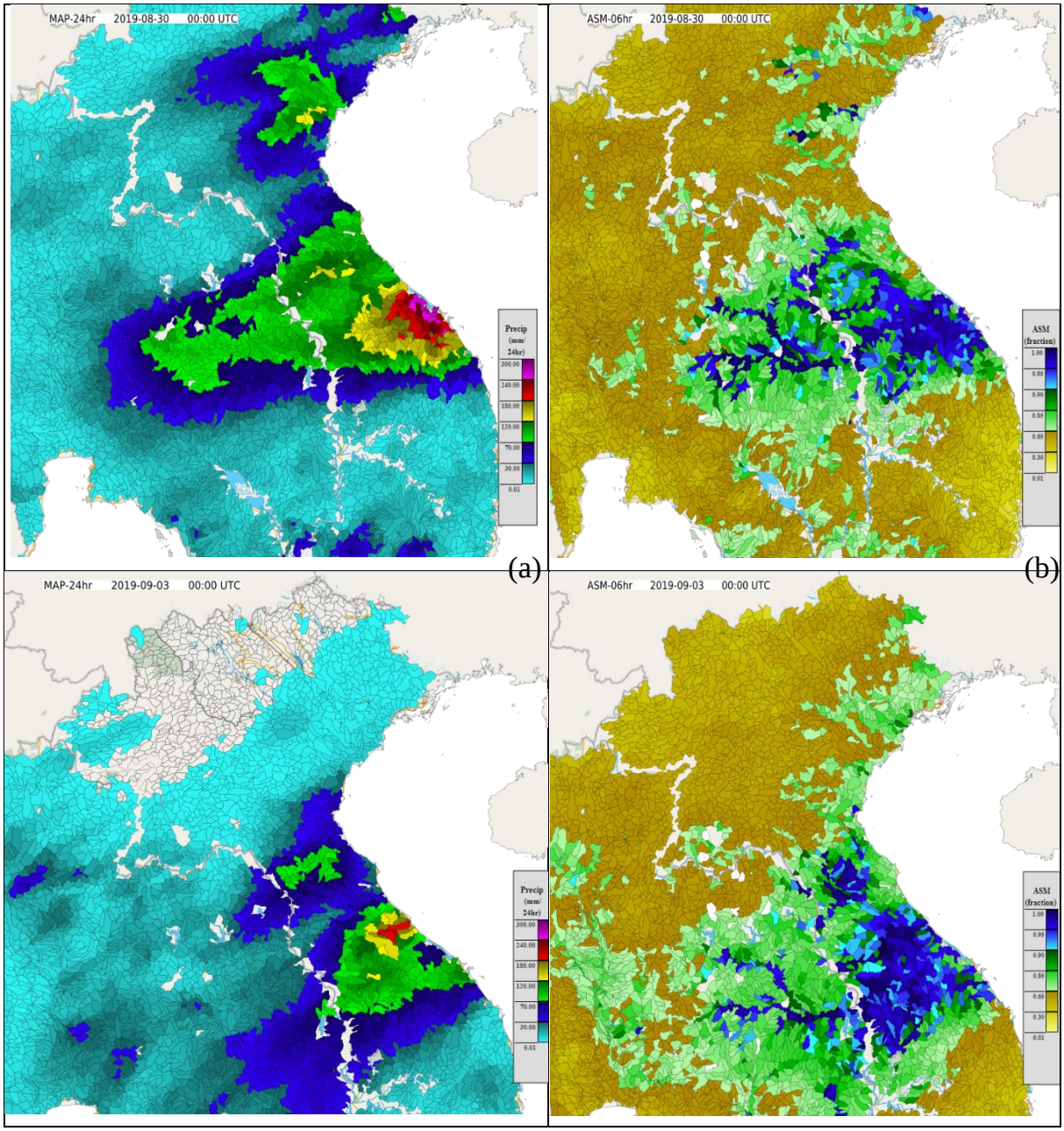


Figure 5.4-5: Flash Flood Guidance product (a) MAP 24h, (b) ASM-6h on 30 August and on 3rd September at 00:00 UTC (07:00 AM- local time)

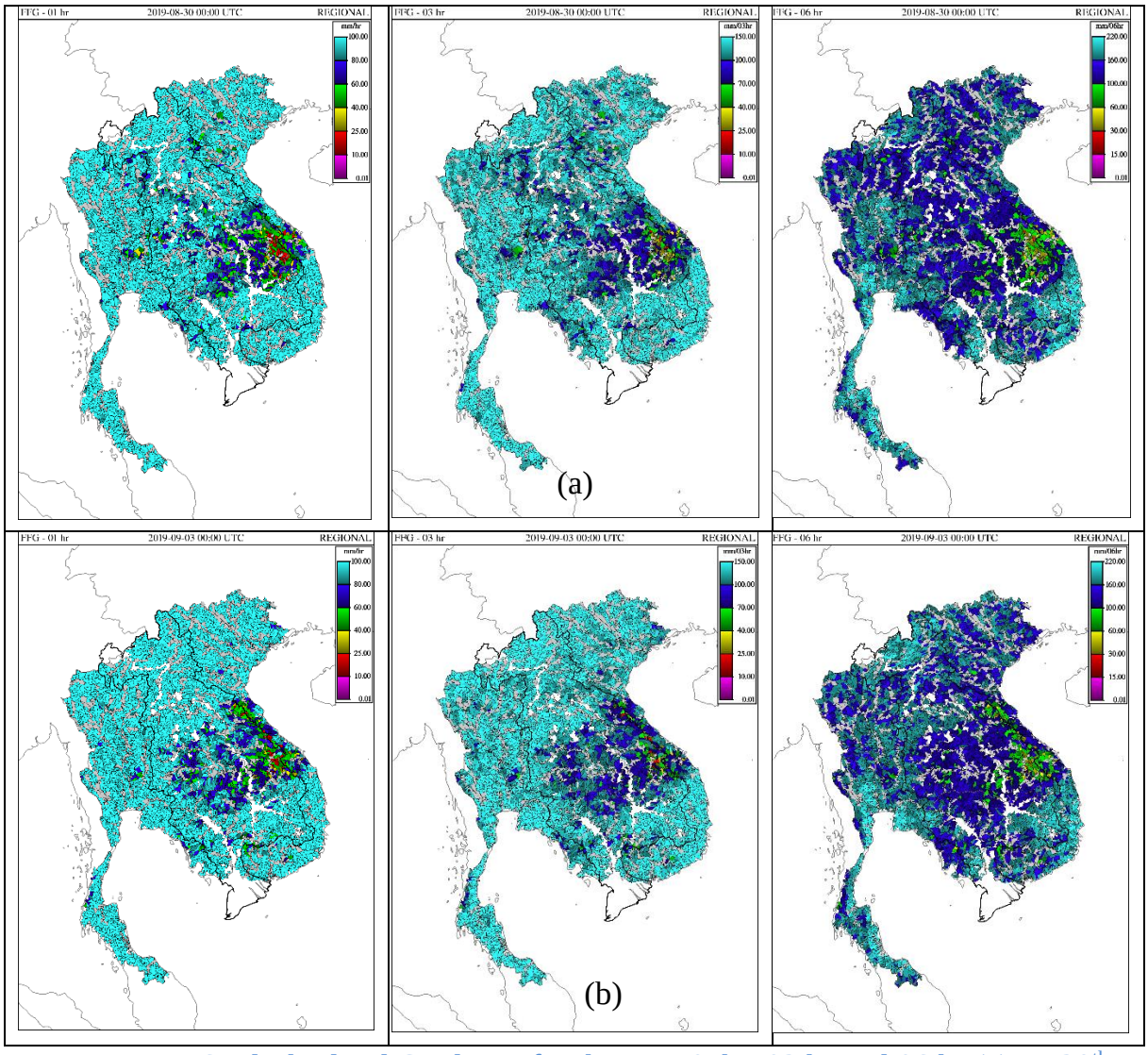


Figure 5.4-6: Flash Flood Guidance for the next 01hr, 03 hr and 06 hr (a) on 30th August 2019 and (b) on 03rd September 2019 in LMB.

Table 5.4-1: Flash flood guidance detected by MRCFFG system in Viet Nam on 30th August 2019 at 00 UTC (07: 00 AM Local time)

Date of FFG products	30/08/2019 00:00	UTC time						
1hour Flash Flood Guidance in Vietnam			**3hours Flash Flood Guidance in Vietnam**			**6hours Flash Flood Guidance in Vietnam**		
Provinces	Districts	FFG value	Provinces	Districts	FFG Value	Provinces	Districts	FFG Value
Gia Lai	Ia Grai	22.95	Gia Lai	Ia Grai	31.48	Gia Lai	Ia Grai	41.19
Kon Tum	Ngoc Hoi	20.16	Gia Lai	Ia Grai	36.33	Gia Lai	Ia Grai	46.55
Quang Nam	Hien	20.16	Kon Tum	Ngoc Hoi	29.14	Quang Nam	Hien	55.13
Quang Nam	Dai Loc	22.99	Thua Thien Hue	A Luoi	34.37	Kon Tum	Ngoc Hoi	39.45
			Quang Nam	Hien	28.16	Thua Thien Hue	A Luoi	44.27
			Quang Nam	Hien	39.83	Quang Nam	Hien	36.97
			Da Nang	Hoa Vang	37.96	Quang Nam	Hien	49.93
			Quang Nam	Hien	36.77	Da Nang	Hoa Vang	48.88
			Quang Nam	Dai Loc	31.5	Quang Nam	Hien	47.25
						Quang Nam	Dai Loc	55.58
						Quang Nam	Dai Loc	41.04
						Quang Nam	Que Son	52.3

Table 5.4-2: Flash flood guidance detected by MRCFFG system in Lao PDR on 30th August 2019 at 00 UTC (07: 00 AM Local time).

Date of FFG produ	30/08/2019 00:00	UTC time						
1hour Flash Flood Guidance in Lao			3hours Flash Flood Guidance in Lao			6hours Flash Flood Guidance in Lao		
Provinces	Districts	FFG value	Provinces	Districts	FFG value	Provinces	Districts	FFG value
Saravane	Ta oi	13.44	Saravane	Ta oi	19.77	Saravane	Ta oi	27.29
Saravane	Ta oi	23.58	Saravane	Ta oi	32.85	Saravane	Ta oi	43.09
Champasak	Paksong	10.82	Champasak	Pathoomph	38.36	Champasak	Pathoomph	47.84
Champasak	Paksong	19.23	Champasak	Paksong	16.17	Champasak	Pathoomph	51.5
Sekong	Kaleum	16.81	Champasak	Paksong	25.33	Champasak	Paksong	22.16
Sekong	Kaleum	17.48	Sekong	Kaleum	25.04	Champasak	Paksong	31.94
Sekong	Dakcheung	13.89	Sekong	Kaleum	25.8	Champasak	Paksong	54.34
Sekong	Kaleum	18.37	Sekong	Dakcheung	21.11	Sekong	Kaleum	34.34
Sekong	Kaleum	17.22	Sekong	Kaleum	34.28	Sekong	Kaleum	53.25
Sekong	Kaleum	22.24	Sekong	Kaleum	25.99	Sekong	Kaleum	35.09
Sekong	Lamarm	17.75	Sekong	Kaleum	25.83	Sekong	Dakcheung	29.22
Sekong	Lamarm	17.62	Sekong	Kaleum	29.98	Sekong	Kaleum	44.17
Sekong	Lamarm	17.6	Sekong	Lamarm	25.45	Sekong	Kaleum	35.01
Attapeu	Sanxay	19.69	Sekong	Lamarm	25.03	Sekong	Kaleum	35.3
Attapeu	Sanxay	20.33	Sekong	Lamarm	25.96	Sekong	Kaleum	38.87
Attapeu	Sanxay	24.08	Attapeu	Sanxay	28.24	Sekong	Lamarm	33.99
Attapeu	Sanxay	22.58	Attapeu	Sanxay	28.81	Sekong	Lamarm	33.14
Attapeu	Sanxay	19.08	Attapeu	Sanxay	34.28	Sekong	Lamarm	57.82
Sekong	Dakcheung	14.55	Attapeu	Sanxay	31.73	Sekong	Lamarm	35.73
Sekong	Dakcheung	15.76	Attapeu	Sanxay	27.22	Attapeu	Sanxay	37.84
Sekong	Dakcheung	18.67	Sekong	Dakcheung	21.87	Attapeu	Sanxay	37.67
Attapeu	Sanxay	22.82	Sekong	Dakcheung	23.01	Attapeu	Xaysetha	57.28
Attapeu	Sanxay	24.27	Sekong	Dakcheung	27.37	Attapeu	Sanxay	45.22
Attapeu	Sanxay	16.84	Attapeu	Sanxay	31.2	Attapeu	Sanxay	41.73
Attapeu	Sanxay	17.81	Attapeu	Sanxay	32.94	Attapeu	Sanxay	36.08
Attapeu	Sanxay	21.76	Attapeu	Sanxay	25	Sekong	Dakcheung	30.53
Sekong	Dakcheung	18.85	Attapeu	Sanxay	26.34	Sekong	Dakcheung	30.98
Attapeu	Sanxay	20.7	Attapeu	Sanxay	31.68	Sekong	Dakcheung	37.21
Attapeu	Sanxay	17.15	Sekong	Dakcheung	27.4	Attapeu	Sanxay	40.29
Attapeu	Sanxay	18.52	Attapeu	Sanxay	35.65	Attapeu	Sanxay	42.45
			Attapeu	Sanxay	29.62	Attapeu	Sanxay	34.32
			Attapeu	Sanxay	25.72	Attapeu	Sanxay	36.05
			Attapeu	Sanxay	27.31	Attapeu	Sanxay	42.55
						Attapeu	Phouvong	52.61
						Sekong	Dakcheung	37.13
						Attapeu	Sanxay	45.68
						Attapeu	Sanxay	39.4
						Attapeu	Sanxay	35.51
						Attapeu	Sanxay	37.3

Table 5.4-3: Flash flood guidance detected by MRCFFG system in Cambodia on 30th August 2019 at 00 UTC (07: 00 AM Local time).

Date of FFG products	30/08/2019 00:00	UTC time						
1hour Flash Flood Guidance in Cambodia			3hours Flash Flood Guidance in Cambodia			6hours Flash Flood Guidance in Cambodia		
Provinces	Districts	FFG value	Provinces	Districts	FFG value	Provinces	Districts	FFG value
Ratana Kiri	Veun Sai	23.59	Ratana Kir	Veun Sai	32.56	Ratana Kiri	Veun Sai	42.3
Ratana Kiri	Andoung Meas	22.01	Ratana Kir	Ta Veaeng	37.02	Ratana Kiri	Ta Veaeng	46.57
			Ratana Kir	Andoung Mea	30.21	Ratana Kiri	Andoung Meas	39.17
						Preah Vihear	Choam Khsant	56.97

Table 5.4-4: Flash flood guidance detected by MRCFFG system in Thailand on 31st August 2019 at 00 UTC (07: 00 AM Local time).

Date of FFG products	31/08/2019 06:00	UTC time						
1hour Flash Flood Guidance in Thailand			3hours Flash Flood Guidance in Thailand			6hours Flash Flood Guidance in Thailand		
Provinces	Districts	FFG value	Provinces	Districts	FFG Value	Provinces	Districts	FFG Value
			Prachinbur	Prachantakham	35.16	Prachinburi	Prachantakham	46.33
			Nakhon Na	Pak Phli	35.96	Sa Kaeo	Muang Sra Kae	54.86
						Nakhon Nayok	Pak Phli	45.7
						Prachinburi	Muang Prachin	52.88

Table 5.4-5: Flash flood guidance detected by MRCFFG system in Viet Nam on 03rd September 2019 at 00 UTC (07: 00 AM Local time).

Date of FFG products	03/09/2019 00:00	UTC time						
1hour Flash Flood Guidance in Vietnam			3hours Flash Flood Guidance in Vietnam			6hours Flash Flood Guidance in Vietnam		
Provinces	Districts	FFG value	Provinces	Districts	FFG Value	Provinces	Districts	FFG Value
Quang Tri	Huong Hoa	16.24	Quang Tri	Huong Hoa	24.07	Quang Tri	Huong Hoa	32.89
Quang Binh	Minh Hoa	16.45	Quang Binh	Minh Hoa	24.08	Quang Binh	Minh Hoa	32.52
Quang Nam	Hien	20.36	Quang Nam	Hien	28.59	Ha Tinh	Huong Son	57.65
Quang Tri	Da Krong	16.38	Quang Tri	Da Krong	24.53	Quang Nam	Hien	37.63
Thua Thien Hue	A Luoi	21.42	Thua Thien Hue	A Luoi	29.53	Quang Tri	Da Krong	33.48
			Quang Nam	Hien	37.42	Thua Thien Hue	A Luoi	38.64
			Quang Nam	Que Son	32.68	Quang Nam	Dai Loc	54.8
						Kon Tum	Dak To	49.54
						Kon Tum	Dak Glei	59.1
						Quang Nam	Que Son	39.88

Table 5.4-6: Flash flood guidance detected by MRCFFG system in Lao PDR on 03rd September 2019 at 00 UTC (07: 00 AM Local time).

Date of FFG produc	03/09/2019 00:00	UTC time						
1hour Flash Flood Guidance in Lao			3hours Flash Flood Guidance in Lao			6hours Flash Flood Guidance in Lao		
Provinces	Districts	FFG value	Provinces	Districts	FFG value	Provinces	Districts	FFG value
Saravane	Ta oi	16.4	Saravane	Ta oi	22.98	Saravane	Ta oi	58.72
Bolikhamxay	Khamkheut	17.43	Bolikhamxay	Khamkheut	25.8	Khammuane	Nakai	50.94
Champasak	Paksong	19.24	Champasak	Paksong	25.43	Bolikhamxay	Khamkheut	35.08
Champasak	Paksong	24.46	Champasak	Paksong	30.75	Khammuane	Bualapha	53.45
Sekong	Kaleum	18.47	Sekong	Kaleum	26.57	Champasak	Pathoomph	53.46
Sekong	Kaleum	16.8	Sekong	Dakcheung	34.33	Champasak	Pathoomph	50.96
Sekong	Kaleum	21.54	Sekong	Kaleum	24.67	Champasak	Paksong	32.32
Sekong	Kaleum	17.25	Sekong	Kaleum	30.34	Champasak	Paksong	37.49
Sekong	Lamarm	17.63	Sekong	Kaleum	24.05	Champasak	Paksong	53.4
Sekong	Lamarm	14.08	Sekong	Lamarm	25.12	Sekong	Kaleum	35.64
Attapeu	Sanxay	17.13	Sekong	Lamarm	20.93	Sekong	Dakcheung	43.43
Sekong	Dakcheung	24.57	Attapeu	Sanxay	25.18	Sekong	Kaleum	33.41
Savannakhet	Sepone	22.04	Attapeu	Sanxay	35.92	Sekong	Kaleum	39.95
Sekong	Dakcheung	23.89	Sekong	Dakcheung	32.42	Sekong	Kaleum	31.81
			Savannakhet	Sepone	30.89	Sekong	Lamarm	33.38
			Sekong	Dakcheung	32.73	Sekong	Lamarm	28.3
						Sekong	Lamarm	53.77
						Attapeu	Sanxay	51.12
						Attapeu	Sanxay	33.47
						Attapeu	Sanxay	45.22
						Sekong	Dakcheung	40.97
						Sekong	Dakcheung	56.88
						Attapeu	Sanxay	59.14
						Savannakhet	Sepone	40.85
						Sekong	Dakcheung	42.69
						Khammuane	Nakai	59.81

5.4.4 Conclusions

During 29 August – 3 September 2019, the heavy rain from Tropical storm PODUL and its Depression resulted in some widespread flash flood in some areas in the province of Lao PDR, Viet Nam, and Cambodia on 30th August 2019 and on 03rd September 2019, and Thailand on 31st August. The MRCFFGS detected some warning Flash Flood districts areas in the province of Lao PDR (Attapeu, Champasak, Savannakhet, Saravane, Khammuane, Sekong) and province of Viet Nam (Quang Binh, Quang Tri, Thua Thien Hue, Gia Lai), and province Ratana Kiri of Cambodia. See Annex for the verification flash flood occurred with media.

5.5 Flash flood events on 31st October 2019 in Central Highland of Viet Nam, caused by typhoon MATMO

5.5.1 Weather Condition during

The monsoon trough lay across the lower northern, upper central, eastern and lower northeastern parts toward the low-pressure cell over the middle South China Sea during early period. After that, the monsoon trough moved southward to lie across the southern part during mid-period associated with southwest monsoon prevailed over the Andaman Sea, southern part, and the upper Gulf of Thailand during early and mid-period. By the way, the moderate high-pressure area from China extended to cover Thailand and the South China Sea during mid and late period. In addition, the easterly wind prevailed over the Gulf of Thailand and southern part during late period. These conditions caused abundant rainfall over upper Thailand during the first half of the period then decreasing in rainfall. Southern part received rainfall throughout the period mainly along east coast (see figure 5.5-1).

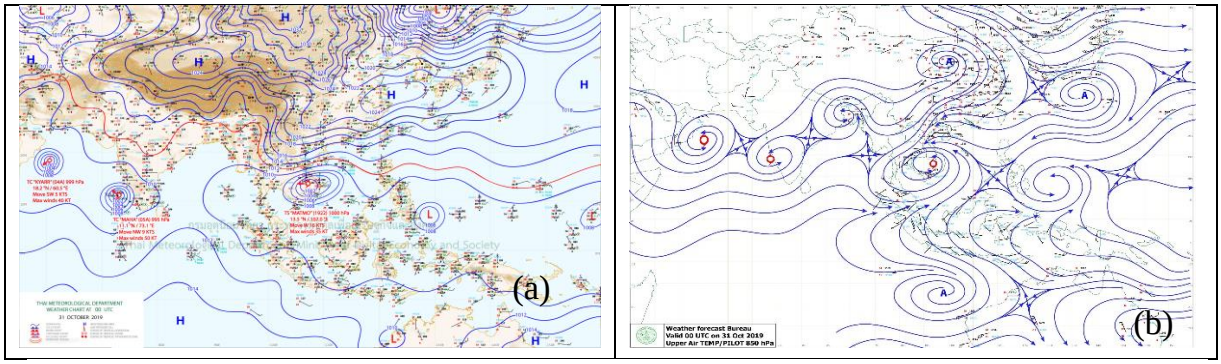


Figure 5.5-1: (a) Weather chart at 00:00 UTC, (b) Upper Air TEMP/Pilot 850 hPa on 31st October 2019

Source: TMD

Typhoon MATMO: A tropical depression formed near Palau on 28th October 2019 and made landfall in Vietnam on 30th October as it intensified to a tropical storm and was named "MATMO". The storm brought rainfall to Cambodia and Thailand, while the heaviest rainfall occurred in Vietnam, causing flooding and road closures. The storm quickly weakened to tropical depression status and dissipated, with its remnants later emerging into the North Indian Ocean on o2rd November. Figure 5.5-2 presents the track of Typhon MATMO.

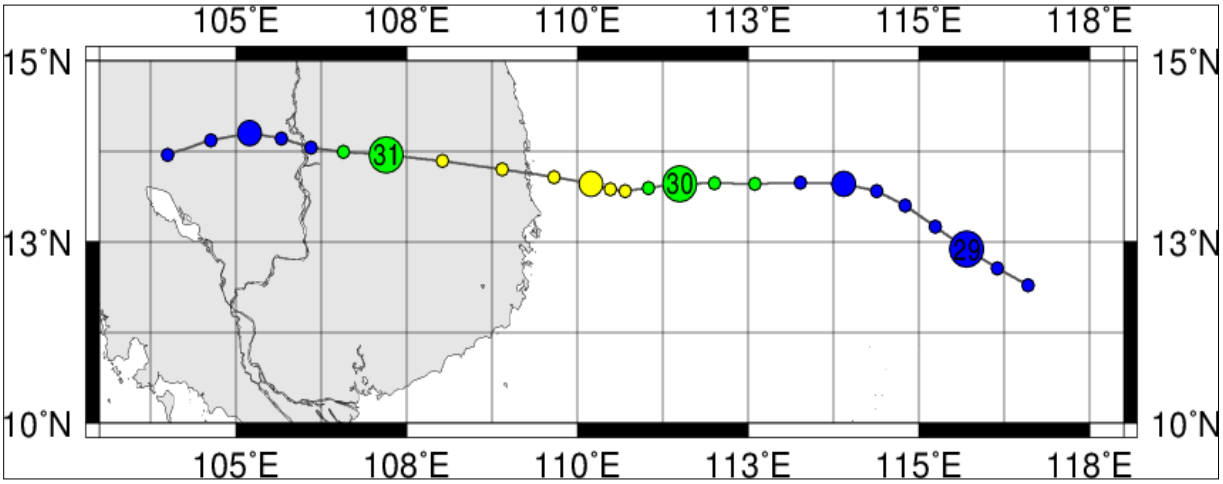


Figure 5.5-2: The track of typhoon "**MATMO"**

5.5.2 Heavy rainfall in the Central – Highland of Viet Nam on 29th – 31st October

During period, the heavy rain occurred in some areas in the Central – Highland of Viet Nam, special at Phu Yen, Binh Dinh and Khanh Hoa provinces caused by influence typhoon MATMO; especial the accumulate rainfall observed at An Khe 165mm, Ayunpa 114mm, Dong Hoi 180mm, A Luoi 125 mm.

5.5.3 Flash flood event on 26th November 2018 in southern part of Viet Nam.

The soils moisture previous 06 hours from MRCFFGS, the soil maybe has been saturated in some areas in the northern part Lao PDR, Central of Vietnam, Eastern part of Thailand, and Northern part of Cambodia (see figure 7.3-1). The products of FFG from MRCFFGS for the next 01, 03 and 06 hr products on 30th, 31st August and on 3rd September 2019 were awarded warning for LMB (Figure 4.3.4-5). Some of those detection results (including time and space) are also corrected with newspaper and actual the flash flood occurred in the Mekong region (table 4.3.5-1).

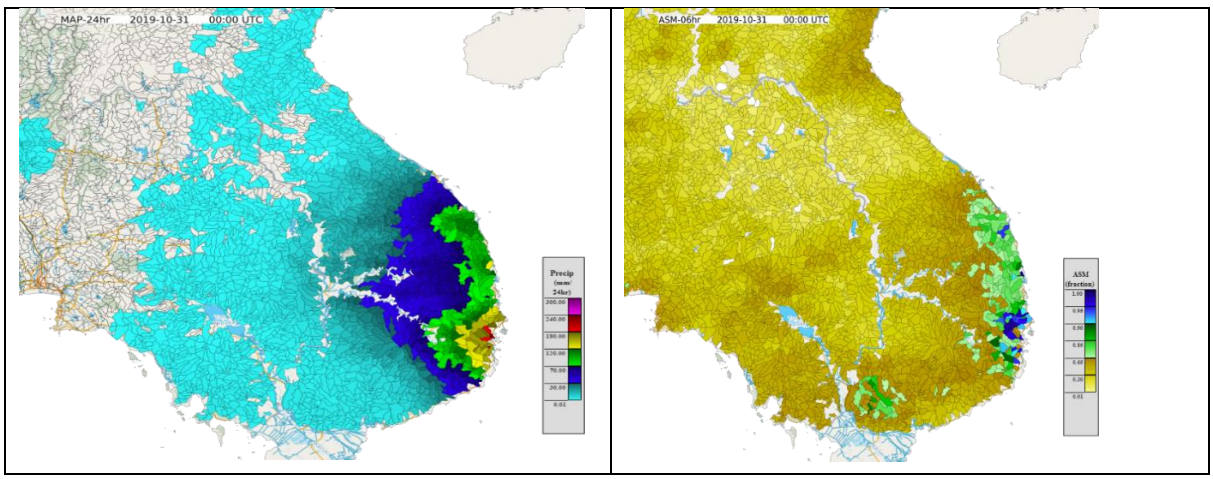


Figure 5.5-3: MAP 24h and ASM-6h on 31st Octorber 2019
at 00:00 UTC (07:00 AM- local time)

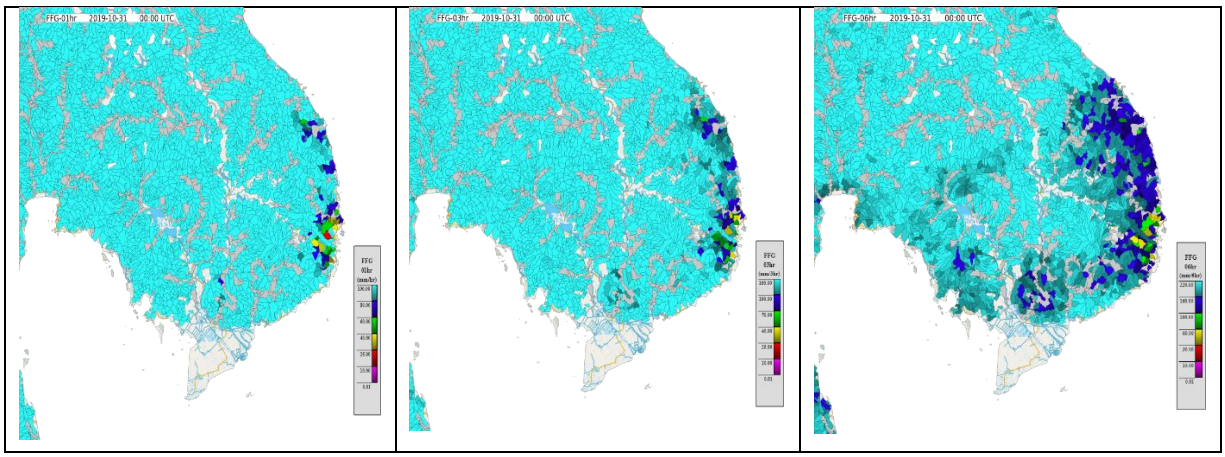


Figure 5.5-4: FFG for the next 01hr, 03 hr and 06 hr
on 31th October 2019 at 00:00 UTC (07:00 AM Local time)

Table 5.5-3: FFG detected by MRCFFG system in Viet Nam
on 31st October 2019 at 00 UTC (07: 00 AM Local time).

31/10/2019 06:00 UTC time							
lood Guidance in Vietnam		3hours Flash Flood Guidance in Vietnam			6hours Flash Flood Guidance in Vietnam		
Districts	FFG value	Provinces	Districts	FFG Value	Provinces	Districts	FFG Value
		Phu Yen	Tuy Hoa	37.73	Binh Dinh	Phu Cat	56.94
					Phu Yen	Tuy Hoa	47.17
					Khanh Hoa	Van Ninh	51.65

5.5.4 Conclusions

- The appearing of the storm in November in the East Sea were not abnormal climate characterizes but also it landed in the South of Vietnam was more abnormal climate's character of tropical typhoon in the East Sea.
- The influence by typhoon's circulation has caused unusually heavy rainfall in southern part of Vietnam, then flash and landslide occurred in some areas in this region.
- The MRCFFGS detected some flash flood areas by the locations, however by the time to occur has underestimate by actual happened of flash flood event.

5.6 Flash flood event on 11st November 2019 in Southern part of Viet Nam

5.6.1 Weather Condition during 04th – 10th November 2019

The moderate high-pressure area from China extended its ridge to cover upper the LBM on the first day of the week and later weakened. After that, another high-pressure area from China extended its ridge to cover the mention area during the second half of the week. These conditions caused cool weather nearly the whole areas of the northern and northeastern parts and cool weather in several areas of the rest parts mainly during the second half of the week. Figure 5.6-1 (a) and (b) show the weather map in LBM on 04th and 11th November 2019.

(b)

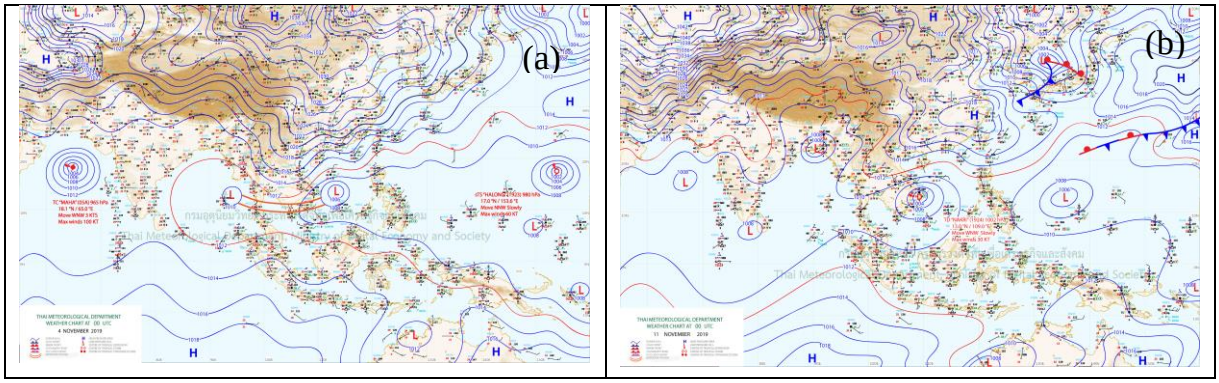


Figure 5.6-1 (a) Weather map on 04th November,
(b) Weather map on 11th November 2019

Tropical storm "NAKRI": On November 5, 2019, a depression off the coast of the Philippines developed into Tropical Depression. This depression intensified to become the twenty fourth tropical storm of the season and was named Nakri by JMA. Original forecasts showed it hitting Vietnam as a minor tropical storm, or a depression. However, on November 7, unexpected strengthening occurred, and the storm intensified into a typhoon. On November 9, NAKRI began to weaken as it dropped below typhoon intensity because of the strong wind shear. In addition, the monsoon trough lies across the upper southern part during the first half of the week by influence from NAKRI. Figure 5.6-2 shows the track of Tropical storm NAKRI.

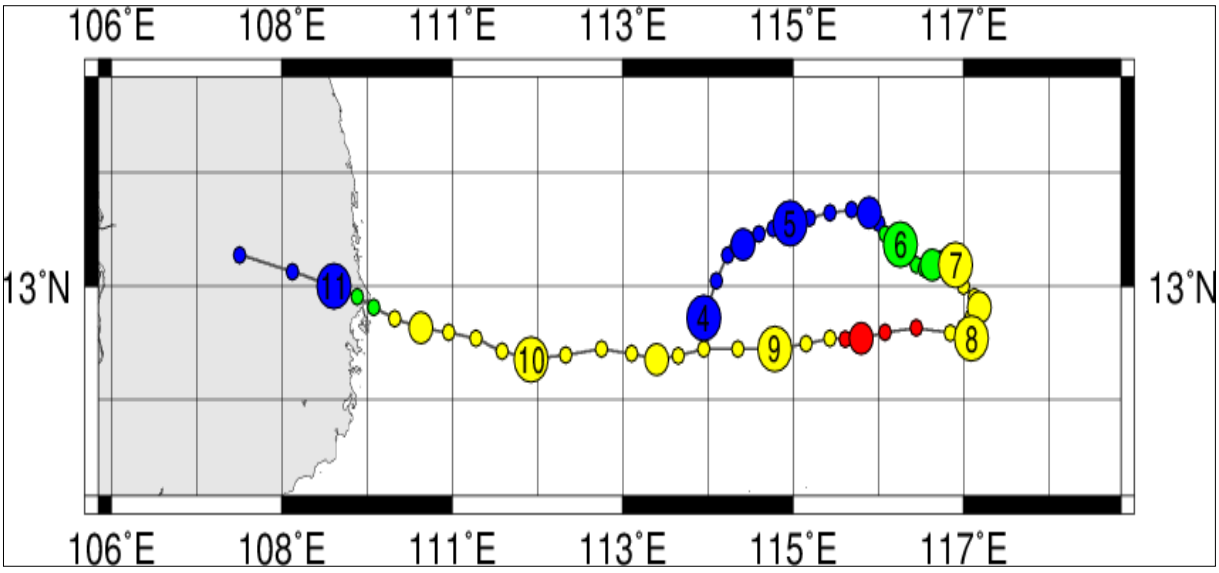


Figure 5.6-2: The track of typhoon "**NAKRI**"

5.6.2 Heavy rain in the Central Highland part of Viet Nam caused by NAKRI on

Despite at that time is out-of-season of annual storms feature over the East Sea, however, it still has a hit of tropical storm NAKRI to the southern provinces of Vietnam. It is caused

heavy rain for these provinces, especially in Dak Nong and Khanh Hoa provinces. The intensity of rainfall measured in a day reached more than 200mm or 300m, such as Buon Ma Thuot (189 mm on 11 Nov 2019), Mdrack (320mm on 11 Nov 2019). This rainfall also has caused some flash flood and landslide events occurred in some areas of the provinces (see figure 5.6-3 and 5.6-4)

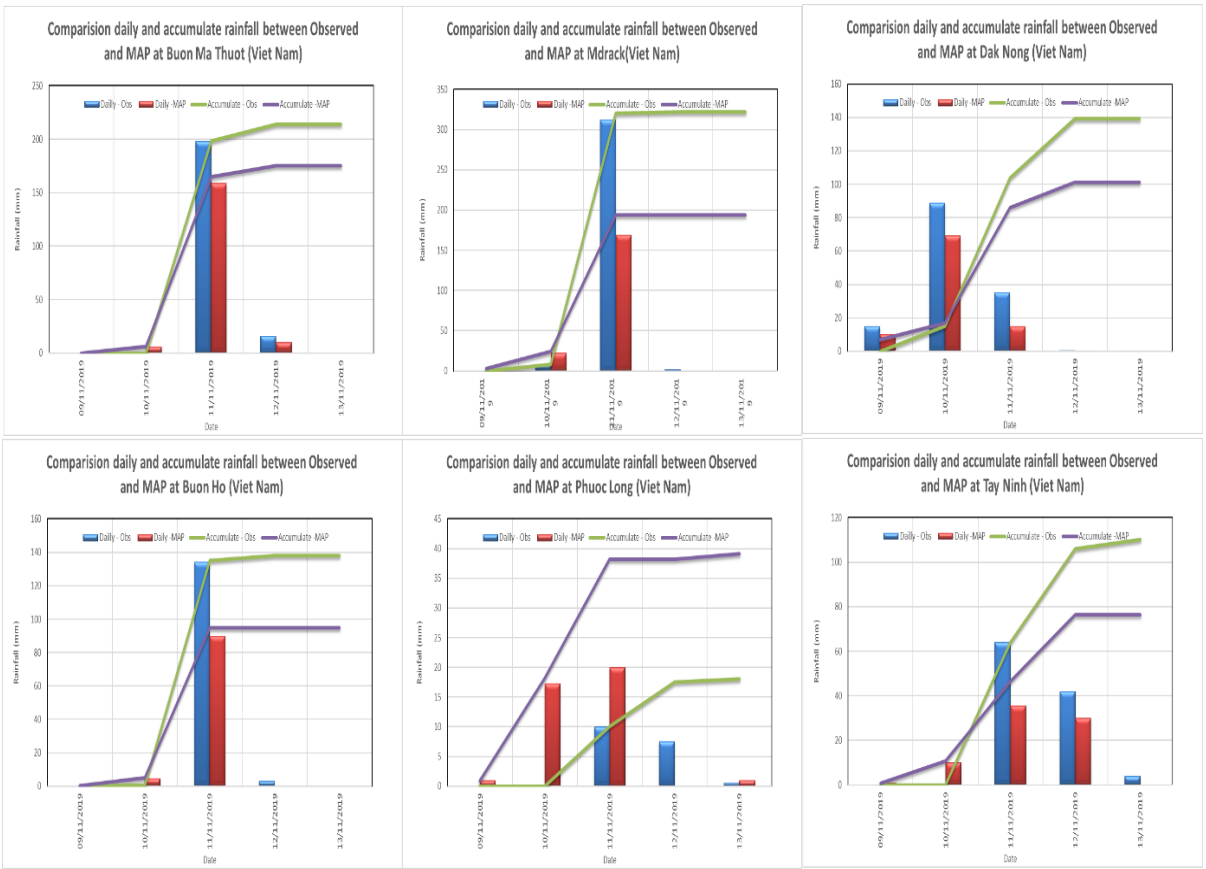


Figure 5.6-3: Comparison daily and accumulate rainfall between observed and Mean Areal Precipitation at some location in LMB (from 25th July to 05th August 2019)

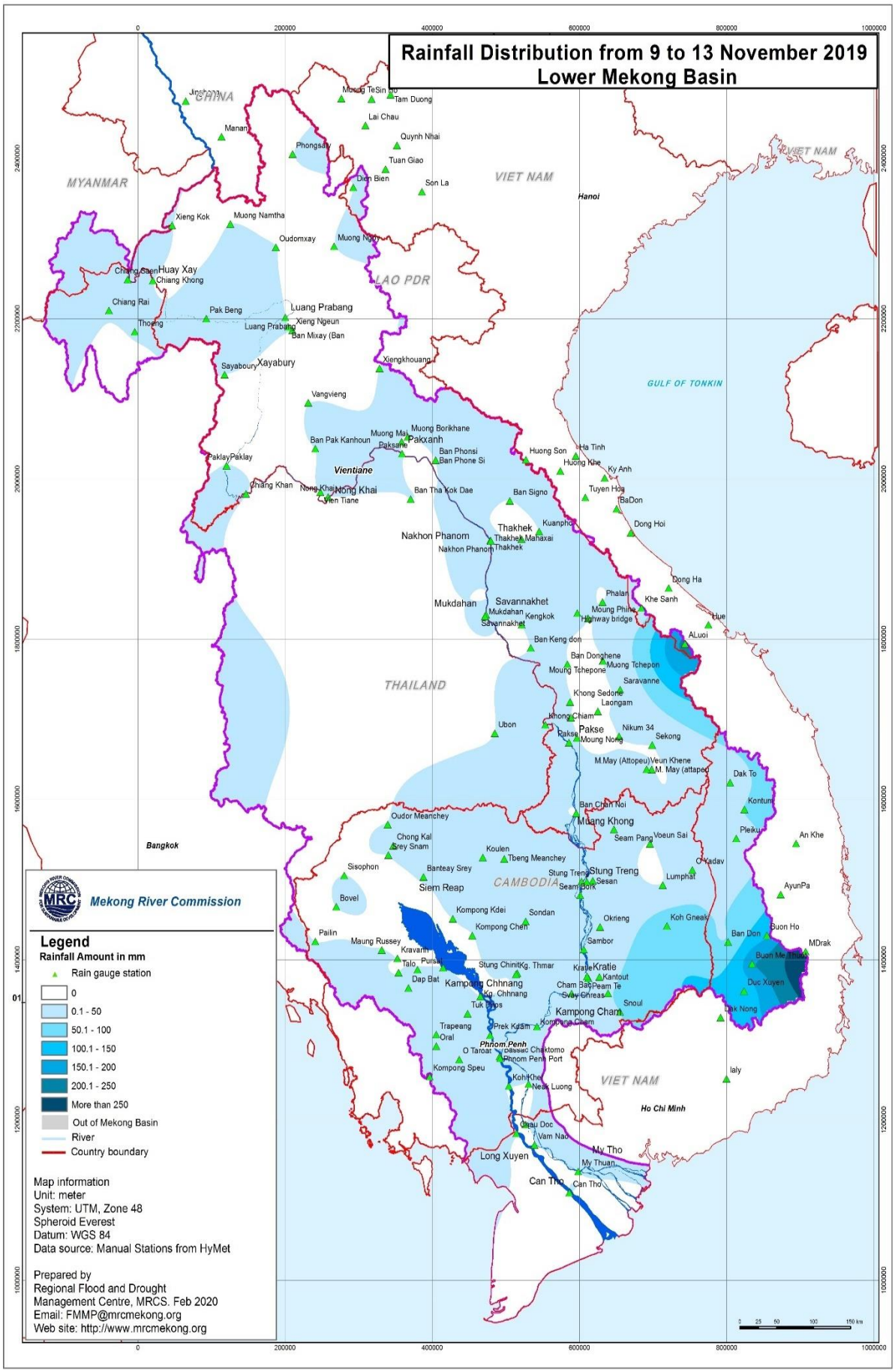


Figure5.6-4 Rainfall distribution during 09th – 13th November 2019 in LBM

5.6.3 Flash flood event in Central Highland parts of Viet Nam on 11th November

The MRCFFGS had been detected the Flash FLood guidance in some areas in Central Highland Central Viet Nam when that time was out of flood season in the LMB. However, as the figure 5.6-3 above, the satellite rainfall were estimated from MRCFFGS at some areas in Central Highland part of Viet Nam still underestimate to compare with the measure. Especially, at Mdrak, Dak Lak Viet Nam, the daily rainfall (on 11 Nov 2019) was observed 300 mm while MAP was 200 mm. Figure 5.6.5 and figure 5.6.6 present the MRCFFGS' products on 11th November 2019.

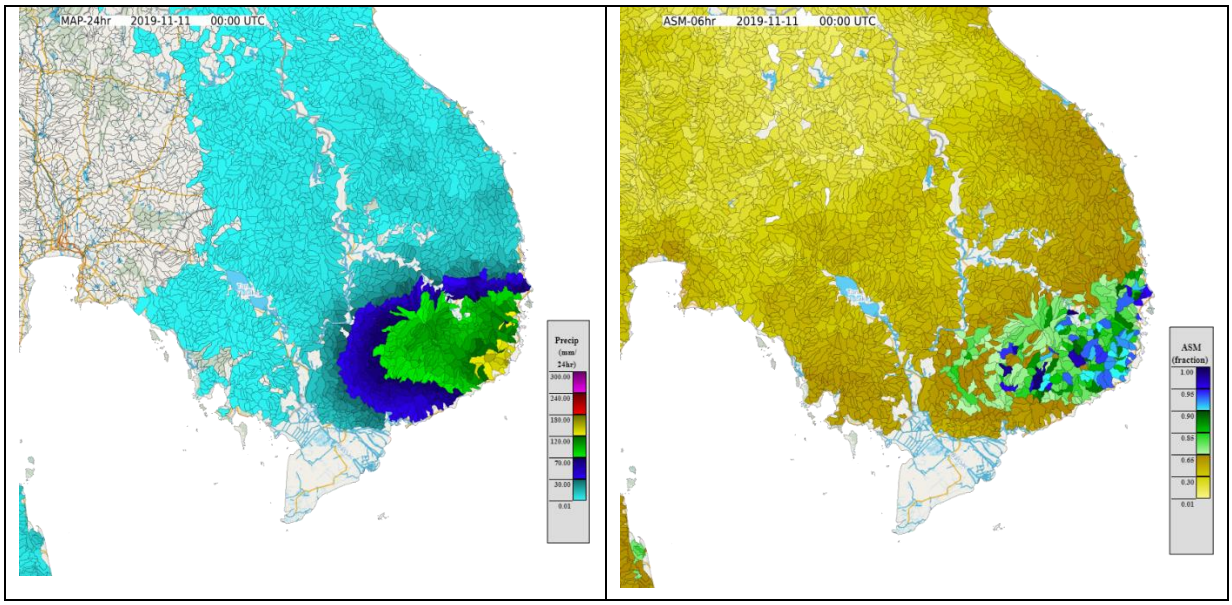


Figure 5.6-5: MAP 24h and ASM-6h on 11th Octorber 2019 at 00:00 UTC (07:00 AM- local time)

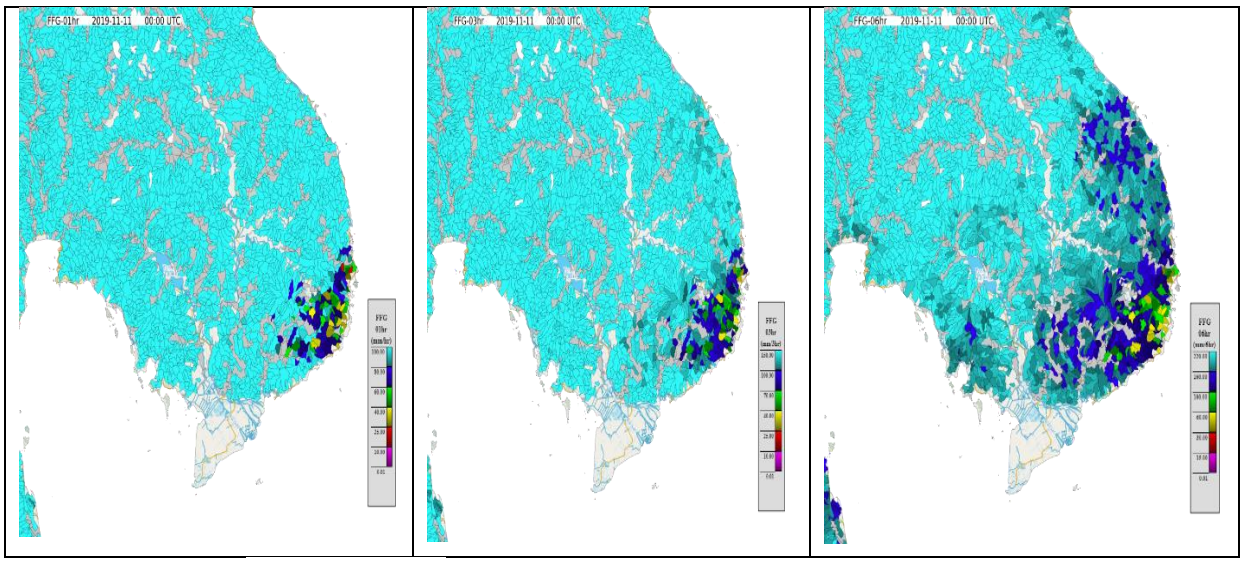


Figure 5.6-6: : FFG for the next 01hr, 03 hr and 06 hr on 11th October 2019 at 00:00 UTC (07:00 AM Local time)

Table 5.6-1 Flash flood guidance detected by MRCFFG system in Viet Nam on 11th November 2019 at 00 UTC (07: 00 AM Local time).

Date of FFG products	11/11/2019 06:00 UTC time							
1hour Flash Flood Guidance in Vietnam			3hours Flash Flood Guidance in Vietnam			6hours Flash Flood Guidance in Vietnam		
Provinces	Districts	FFG value	Provinces	Districts	FFG Value	Provinces	Districts	FFG Value
Phu Yen	Tuy Hoa	21.82	Phu Yen	Tuy Hoa	28.43	Phu Yen	Tuy Hoa	35.38
Khanh Hoa	Van Ninh	24.3	Khanh Hoa	Van Ninh	31.36	Khanh Hoa	Van Ninh	38.7
Khanh Hoa	Ninh Hoa	20.06	Khanh Hoa	Ninh Hoa	26.88	Khanh Hoa	Ninh Hoa	34.35
Lam Dong	Don Duong	23.88	Khanh Hoa	Khanh Vinh	34.47	Khanh Hoa	Khanh Vinh	44.87
Binh Thuan	Tanh Linh	21.61	Lam Dong	Don Duong	32.72	Khanh Hoa	Khanh Son	53.03
Lam Dong	Lac Duong	23.61	Binh Thuan	Tuy Phong	35.14	Ninh Thuan	Ninh Hai	55.04
			Binh Thuan	Tanh Linh	29.01	Lam Dong	Don Duong	42.46
			Lam Dong	Lam Ha	32.84	Ninh Thuan	Ninh Son	59.07
			Lam Dong	Lac Duong	31.53	Lam Dong	Don Duong	51.73
						Binh Thuan	Tuy Phong	44.55
						Binh Thuan	Bac Binh	59.56
						Lam Dong	Don Duong	56.49
						Binh Thuan	Tanh Linh	37.06
						Binh Thuan	Ham Thuan Bac	56.9
						Dak Lak	Lak	59.07
						Dak Lak	Dak Nong	52.23
						Lam Dong	Lam Ha	41.46
						Lam Dong	Lac Duong	40.23
						Dak Lak	Krong Bong	52.75

5.6.4 Conclusions

- The appearing of the storm in November in the East Sea were not abnormal climate characterizes but also it landed in the South of Vietnam was more abnormal climate's character of tropical typhoon in the East Sea.
- The influence by typhoon's circulation has caused unusually heavy rainfall in southern part of Vietnam, then flash and landslide occurred in some areas in this region.
- The MRCFFGS detected some flash flood areas by the locations, however by the time to occur has underestimate by actual happened of flash flood event.

6 Conclusions and recommendations

6.1 Conclusions

Flash floods in the Mekong region is a recurrent event which has the potential to adversely affect economic, human, lives, properties, and infrastructures. Currently, the Lower Mekong region have become increasingly more concerned with flash floods and are looking for ways to improve flood preparedness to limit the extent of damage. According to the media reported (see appendix A), flash floods and landslides occur very often in mountainous areas of the upper and central of Mekong region.

Since 2010, the MRCFFG system has been operating successfully. It provides products to support the development of warning and estimate the risk of flash flooding from rainfall events in the sub-basins of the MRC member countries. The main aim of this report is to evaluate the performance of MRCFFG system in the MRC member countries for the detection of the risk areas of potential flash floods during the 2019 flood season from May until the late of November.

The report does not cover all the flash flooding that occurred in 2019 flood season, it is based on the available flash flood information that was collected from the media (see appendix A). However, it is very difficult to evaluate the MRCFFG results using media information due to in fact flash floods occurred which are difficult to access and there are no reports available. The MRCFFG system often indicated a flash flood risk in the flooded areas, but it is lacking an accurate and complete database of flash flood events. This makes it difficult to put a number on the success rate.

There were 29 tropical storms which developed over the Pacific Ocean and or over the East Sea (see table 3.1-1 and figure 3.1-1). There were **five** tropical storms, namely (1) MUN, (2) WIPHA, (3) PODUL, (4) MATMO, (5) NAKRI which caused serious flash floods affecting in the LMB. The other cause of flash floods in the Lower Mekong region is the ITCZ, low pressure and tropical depression which also led to flash flood occurrence at some areas in the Mekong mainstream and its tributaries.

Due to the new server of MRCFFGS have been operated in May 2018, so during the operation in flood season 2019, there were some errors that occurred. However, all of them were found and solved timely by ITs at HRC, RFDMC through the maintenance and close cooperation with HRC, and MRC from RFDMC to ensure that providing Flash Flood Guidance to Users. Annex D presents some problems of MRCFFGS and how to contact with HRC to solve and announcements those problems to MCs.

Most of the flash flood events and areas in the Mekong region were detected by the MRCFFG system (average performance achieved at above-average - 74%). However, some flash flood events during flood season were not detected due to the system model was not simulate the weather factors as correctness to generate soil moisture, flash flood guidance accordingly. Such as did not capture exactly the heavy rain (underestimate/overestimate) caused by ITCZ, tropical storm. Annex E presents the performance achieved flash flood operation for each country of the LMB; base on analyzing MRCFFG products at RFDMC in the flood season 2019.

Finally, it can be stated that the MRCFFG system performance during flood season 2019 could predict expected rainfall amounts with reasonable accuracy; the system is potentially a very effective tool for flash flood forecasting in the Mekong region.

6.2 Recommendations

The recommendations would further develop the MRCFFG system for enhancing the accuracy of flash flood forecasting, and to reduce damage, the risk of lives, properties and also to avoid future catastrophes caused by flash floods are listed below:

- There are remain the failing detection (i.e. underestimated and overestimated) of the MRCFFG's products in the system (FFG, MAP, FFR, ASM) although it was improved by using the bias correction of satellite rainfall since the end of 2017. It is recommended that to improve the Mean Areal Precipitation (MAP) product for reliable rainfall measurement needs to be reviewed the bias correction factor. Once, updated the bias correction factor, should re-run the MRCFFG system, review and verify the results.
- The new server system has been installed and operated since 2018 at the flood center by HRC experts. In fact, during the operation in flood season 2019 some technical errors related to server hardware and software occurred (hard-dish out of memories to store data, miss some time-series products). In order to deal with this problem to ensure the operational tasks that provide flash flood guidance information for MCs and Users, it is recommended to enhance capacity building on maintenance the server for IT in RFDMC.
- For the evaluation of effectively MRCFFG system and to improve the accuracy of the system, it is recommended that to build confidence in the system a more orderly way to collect the information of flash flood is needed. National flood relief authorities should build up a database on the exact location of flash floods and the damage occurrences, and report to the RFDMC. Then the effectiveness of the system can be properly evaluated, and weaknesses of the system identified and rectified.
- The current GIS database such as the village, district and province name and boundary received from national line agencies in 2003. This information may not consistent and out of date with the current GIS database of each country. It is recommended that the updated GIS database is a significant input to issue the warnings on possible flash floods occurrences.
- According to the flash flood information of the media reported, flash flooding occurrences at many districts under Flash Flood Risk (FFR) products for forecast with lead-time longer (12, 24 and 36 hours). These products are computed every six hours and the measure the occurrence of positive forecast flash flood threat (FFFT) over a given forecast period using forecast precipitation to drive the Soil and FFG models. It is recommended that the routine daily operational flash flood forecasts should also taking into account the flash flood watch warnings in cause the extremely weather conditions influence to Flash Flood in the LMB.
- Since MRCFFGS version 2018 was upgraded with new products, especially the Forecast Mean Areal Precipitation (FMAP) for 1,3,6 and 24-hour lead time forecast. Each data of FMAP reflects the intensity of precipitation in sub-basin. It

was produced by using the numerical forecast model (WRF model). This product is very important for flood forecasting in tributaries rivers. Therefore, in case the heavy rain that may appear caused by extreme weather conditions (Typhoon, Tropical Depression, ITCZ) in the LMB these products should be provided for MCs and Users by bulletin via webpage or email.

- The MRCFFG system could contribute to the preparedness by offering the training courses in the use of the system and by urging the countries to alert flash flood warnings. It is recommended that to conduct refreshment training courses of MRCFFG system operation for the purpose to improve on FFG operation, and to exchange the knowledge and experiences on FFG operation with National Hydro-Meteorological Forecasting Center's and the RFDMC operators.
- For effective disaster flash flood risk reduction, it is recommended that the community awareness of flash flood with user agencies is needed. And during the serious weather conditions such as tropical storms, tropical depressions, ITCZ etc. Flash floods can occur at any time at any area of the Mekong region. It is recommended that the daily operational flash flood forecast should update the flash flood warnings on the MRC webpage and publish three times during daytime with 6 hourly intervals, at 07:00 am, 01:00 PM and at 07:00 PM, respectively.

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Annex A: The media reported of flash floods and landslides occurred of Mekong region in flood season 2019

Annex A1: Luang Prabang Villagers Hit by Flash Floods Luang Prabang Villagers Hit by Flash Floods, July 31, 2019

A number of villages in Nan District, Luang Prabang Province have been hit by severe flash floods after torrential rain on Monday evening.

A massive rainstorm has finally broken the severe drought that gripped the country for months, causing flash flooding in Luang Prabang.

The Nan River burst its banks early Monday morning, overflowing into several nearby villages. Nearly 400 families have been affected by the floods, with local authorities providing assistance.

Villagers and their belongings are being moved by boat to higher ground, and so far there have been no reports of injury.

Flood waters nearly reach the rooftops in Nan District, Luang Prabang

The floodwaters began to subside yesterday afternoon, and authorities are now undertaking an assessment of the damage caused to villagers' homes and livelihoods.

The Meteorology and Hydrology Department, Ministry of Natural Resources and Environment, has issued a severe weather warning for many parts of the country, especially the northeast, central and southern regions as a tropical depression will pass over the country in the next few days.

Strong winds and heavy rains are expected, which could cause flash flooding and landslides

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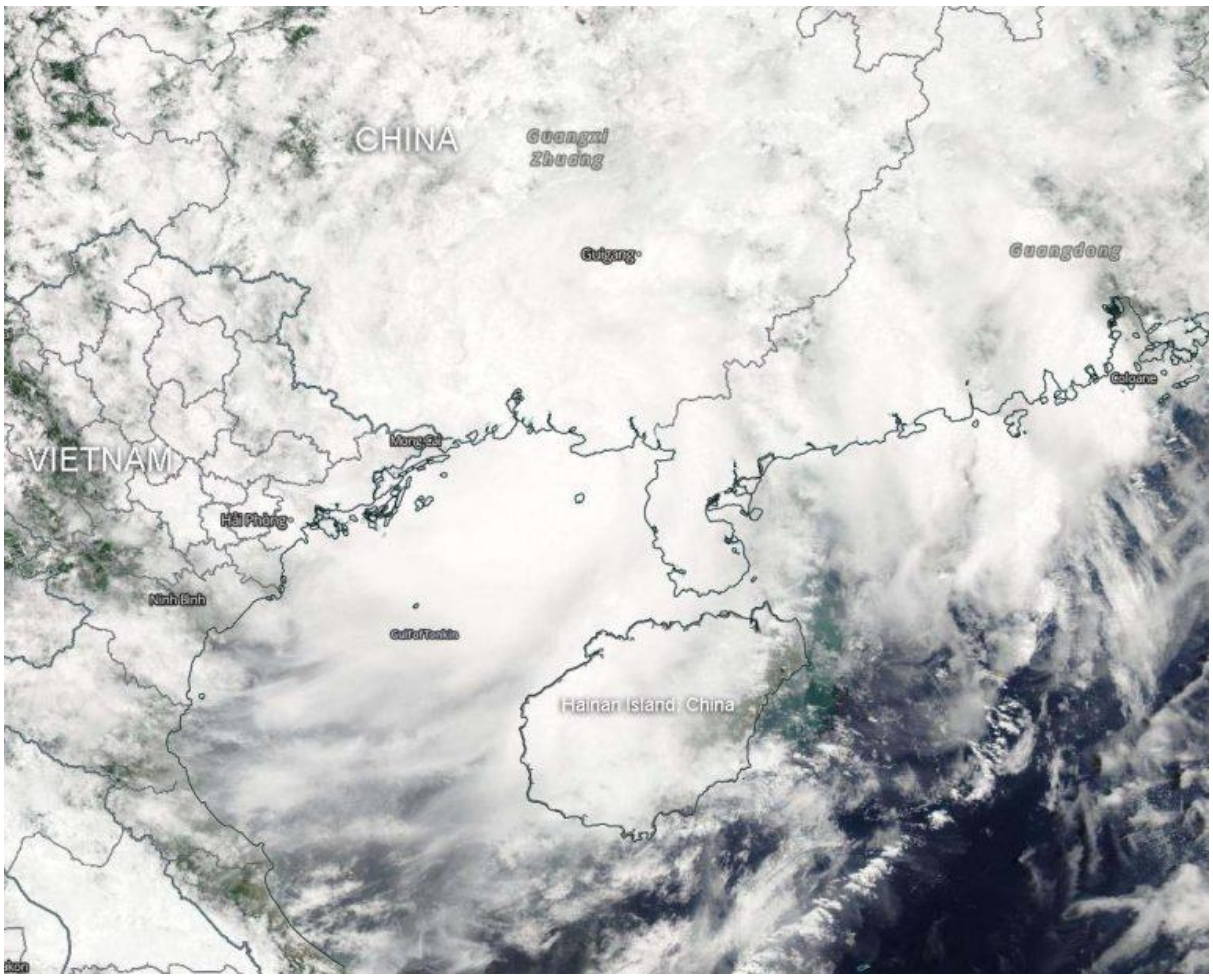
Annex A2: Vietnam – Tropical Storm Wipha Leaves 5 Dead, 13 Missing

5 AUGUST, 2019 BY FLOODLIST NEWS IN ASIA, NEWS

At least five people have died and 13 others are reported missing after Tropical Storm Wipha swept across northern Vietnam.



On Aug. 2, 2019, the MODIS instrument aboard Aqua captured a visible image of Tropical Storm Wipha in the Gulf of Tonkin, South China Sea, headed for landfall in northern Vietnam. Credit: NASA Worldview, Earth Observing System Data and Information System (EOSDIS)

The storm made landfall late on 02 August, 2019 in Quang Ninh province, then weakened in to a tropical depression bringing heavy rainfall, including in the capital Hanoi.

According to a statement by Vietnam's Central Steering Committee for Natural Disaster Prevention, 3 people died and 12 are missing in Thanh Hóa province, where flash flooding has caused severe damage in parts of Quan Son district. Around 20 homes were swept away and 1 person died in the flooding. Two fatalities were also reported in the Muong Lat district of the province. Other fatalities were reported in Bac Kan and Dien Bien provinces.

Wipha also caused flooding and wind damage in parts of Guangxi region and Hainan and Guangdong, provinces in southern China. Haikou, capital of Hainan province, recorded 276.1 mm of rain in 24 hours to 31 July.

Annex A3: Laos seeks Vietnam's help to search for flash flood victims (By Le Hoang Aug 7,2019)

The Luong River in Thanh Hoa Province that connects to the Xia Stream in Laos, where seven Lao people were swept away during flash flood on August 3, 2019. Photo by VnExpress/Le Hoang.

Annex A4: Authorities in Laos's Viengxay District have sought Vietnam's assistance to look for seven people missing in the aftermath of storm Wipha.

Seven people – three males and four females aged four months to 47 years – were swept away by a flash flood triggered by storm Wipha' s aftermath on Xia Stream last Saturday, said authorities in the district of Houaphanh Province.

Viengxay has conducted searches along the stream until the Laos-Vietnam border, but have been unable to find the victims.

As the stream crosses the border into Vietnam's Quan Son District in the central province of Thanh Hoa, Viengxay authorities on Monday sent a letter requesting Quan Son District's assistance in searching for the missing victims.

Thanh Hoa was hardest hit locality in Vietnam by storm Wipha which made landfall in the northern province of Quang Ninh last Friday night before weakening into a tropical

depression and moving deeper inland, bringing heavy rain to northern and north central provinces.

The tropical depression weakened further into a low-pressure system as it moved to northern Laos.

The death toll from storm Wipha in Vietnam has climbed to 12 while nine others are still listed as missing.

15 people were swept away by a flash flood that hit Sa Na Village in Thanh Hoa last Saturday. Seven people have been confirmed dead.

Vietnam experiences a storm season between July and October. There were nine storms last year and four are expected this year.

Natural disasters, mostly floods, storms and landslides, killed 181 people last year and left 37 others missing and caused losses of around VND20 trillion ($858 million).

Annex A5: Vientiane times: *Heavy* rain in some regions of Lao PDR.

LAO PRESS IN FOREIGN LANGUAGES
Vientiane Times
www.vientianetimes.org.la www.vientianetimes.la
65 years 22.3.1955 - 22.3.2020

Authorities in Viengxay district, Huaphan province, are calling for contributions of cash and materials to help with the recovery effort after 18 villages suffered from flooding and landslides. Heavy rain has affected the area since August 3 and seven people are still missing after a landslide. The Viengxay district office has requested money and basic supplies to help people whose homes or property have been inundated. Seven people from two families in Hindam village are still missing after a landslide swept away two houses. The missing members of one family have been named as Mr Yengjingthor, 47, Ms Yai, 45, Mr Yeng, 17, and Mr Jeng, 13. The missing members of the second family are Ms Maisuathor, 22, and two children aged 5 and four months. Floods have submerged 60 hectares of rice fields and 15 hectares of other crops, while five houses have been damaged. Some 140 fishponds, livestock and infrastructure have also been affected. Those interested in helping or donating household items are invited to call local authorities at the district office on 064 315 018 or 020 555 64600. Meanwhile, the search operation for the seven missing people continues, with authorities bringing in excavators to help local people and over 100 army personnel in their search and rescue operations. Conditions are difficult due to large rocks, thick mud, and uprooted trees along a three kilometre stretch of the river. Lao officials are contacting their Vietnamese counterparts to help in the search as Hindam village is located just three kilometres

from the Vietnamese border and the river is also bordered by Vietnam. Many parts of Laos were affected by flash floods, landslides and blocked roads after Tropical Storm Wipha passed over the country from August 4-5. Damage to property in Nan district, Luang Prabang province, has been estimated at over 8.4 billion kip after almost 2,000 people were affected by floods. Some 358 families suffered varying degrees of property damage and 1,722 people in total have been affected, according to a local official. It has been calculated that 14.44 hectares of crops and 52.58 hectares of rice were submerged, 638 bags of rice were damaged and 2,794 poultry and 23 pigs were lost. Two roads, four bridges, five irrigation systems and 28 houses were also damaged.

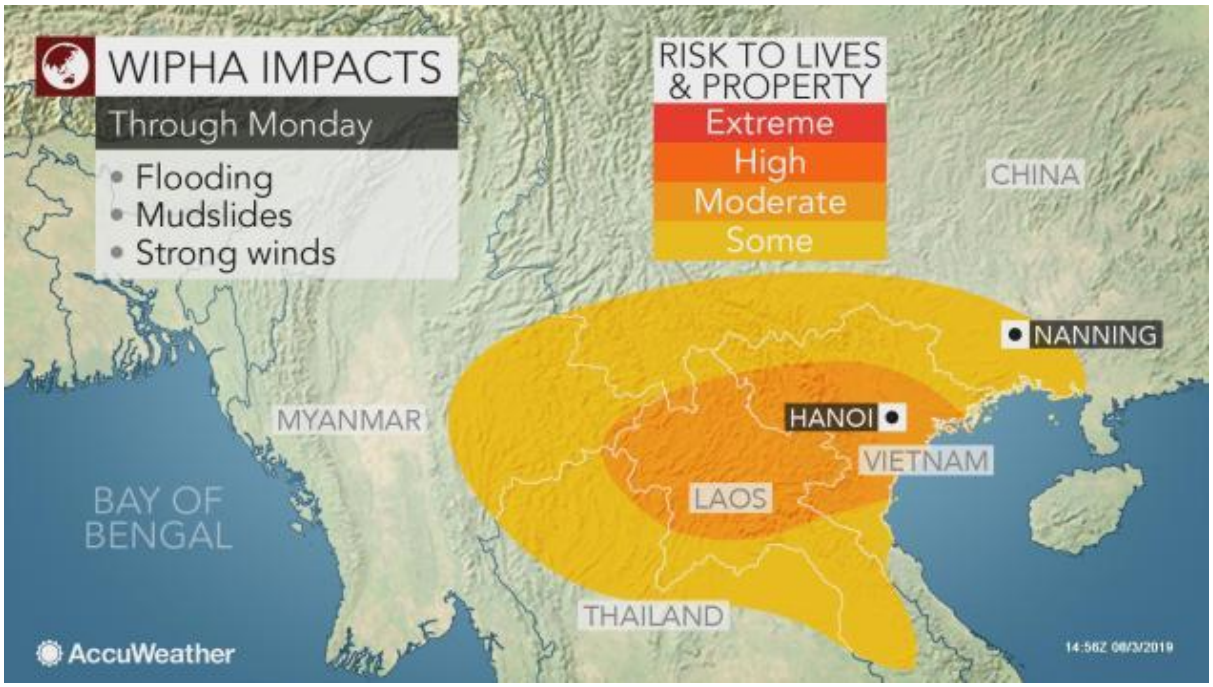
Annex A6: Wipha to unload heavy rain, gusty winds on China, Vietnam into Sunday

By Eric Leister, AccuWeather senior meteorologist
Updated Aug. 3, 2019 11:25 PM

The Hong Kong Observatory issued its first No 8 typhoon signal of the year on July 31, 2019, as Tropical Storm Wipha approached the city. The storm is expected to skirt 300km (190 miles) to the city's southwest, according to the Observatory, which predicted the No 8 signal would remain in place for the rest of the day. The storm is expected to bring heavy showers and squalls to the city.

Tropical Rainstorm Wipha, which formed in the South China Sea between the Philippines and China, will bring the risk of flooding and locally damaging winds to the region through Sunday.

The storm made an initial landfall across China's Leizhou Peninsula on Thursday. Wipha then tracked westward near the coast of China's Guangxi province before making a second landfall into northern Vietnam on Saturday.



Locations from southern China into northern Vietnam, northern Laos, eastern Myanmar and far northern Thailand will need to be on alert for flooding downpours and a heightened risk for mudslides.

Heavy rainfall could reach a total of 100-200 mm (4-8 inches) across the region, with an AccuWeather Local StormMax™ of 380 mm (15 inches) possible from northern Vietnam into northern Laos.

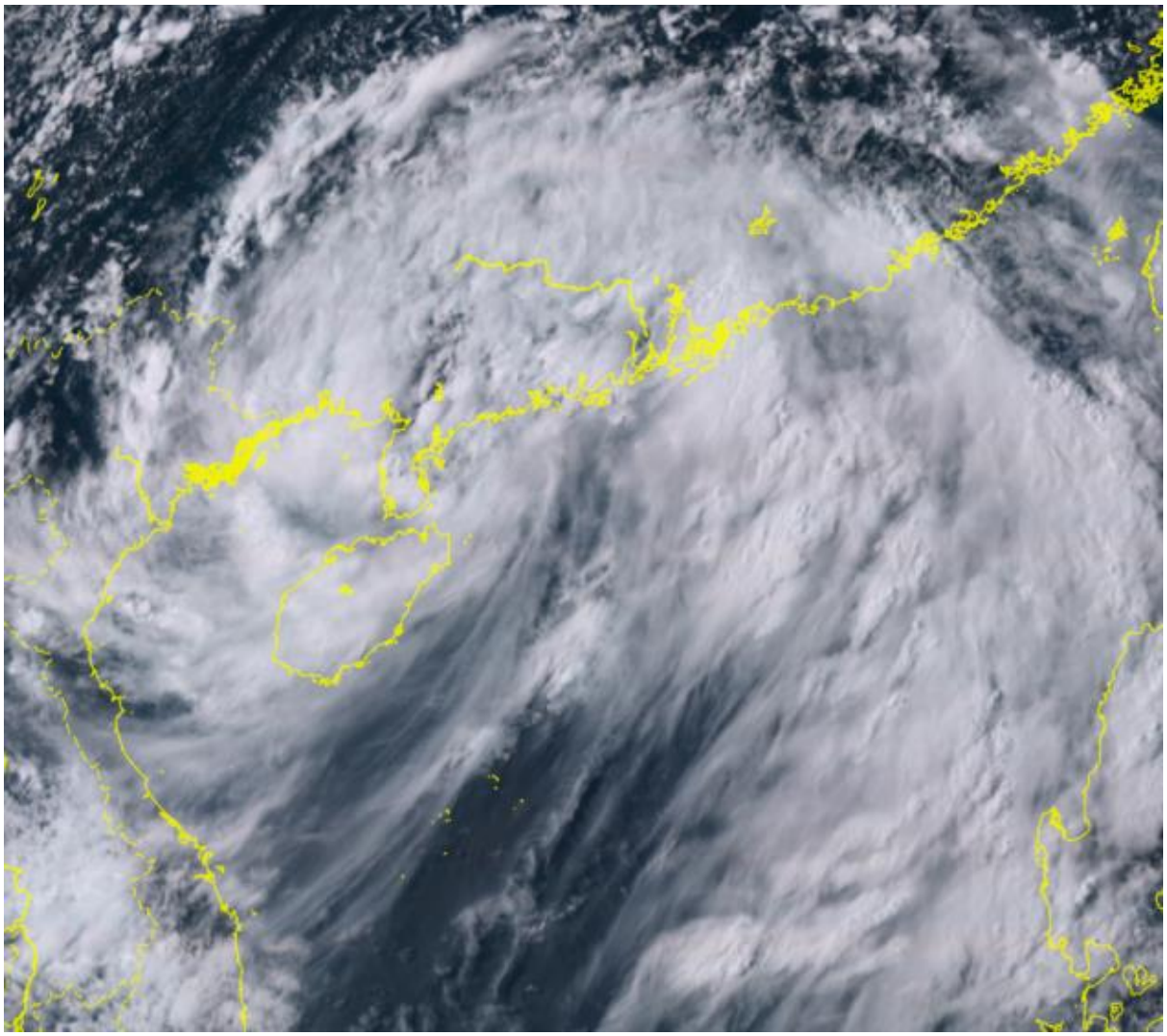
Hanoi dodged the worst of Wipha's wind; however, the city was lashed by more than 125 mm (5 inches) from Friday night into Saturday night. More downpours are expected through the day on Sunday.

Rainbands from Wipha lashed Hong Kong from Wednesday into Thursday bringing around 200 mm (8 inches) of rainfall to the city.

The combination of downpours and frequent wind gusts of 50-65 km/h (30-40 mph) lead to the Hong Kong Observatory issuing a tropical cyclone signal 8, its third highest level, according to Reuters. The warning was lowered to an Amber Rainstorm Warning Signal on Thursday.

The education bureau closed schools on Wednesday, and authorities urged office workers to go home early.

Hong Kong's financial markets were closed early on Wednesday before reopening on Thursday. Brief periods of intense rainfall and gusty winds continued through Friday, resulting in localized flooding and travel delays at times.



Satellite image showing Wipha over northern Vietnam on Saturday, local time. (RAMMB)

For anyone in the path of this storm, heed all advice from local government officials and evacuate if asked. Keep gas tanks filled and cell phones charged.

Despite the storm tracking away from the Philippines, bands of rain will batter western areas of Luzon, including Manila, into this weekend. Localized flooding and travel disruptions are possible each day.

Annex A7: Rainfall effected by Tropical storm "Podul" in Lao PDR

WFP

World Food Programme

SAVING LIVES
CHANGING LIVES

WFP Lao PDR
Country Brief
August 2019

Operational Context

Lao PDR is a least developed country, ranking 139 out of 189 countries in the 2017 Human Development Index. It has one of the lowest population densities in Asia. 23 percent of the population lives below the national poverty line (USD 1.25/day), with a gross national income per capita of USD 2,270 (World Bank 2017). The country is ranked 64 out of 144 in the Global Gender Gap Index 2017.

While Lao PDR has managed to reduce the proportion of hungry poor to 23 percent, the 2015 Global Hunger Index still rates hunger levels as "serious".

Climate change is a key challenge facing rural livelihoods, and the country is vulnerable to climate change due to its low adaptability and its dependence on climate-sensitive natural resources. Changing climate patterns, combined with poor access to both markets and diverse livelihoods, further worsen the situation in remote upland areas, where 25 percent of households are food insecure.

WFP has been present in Lao PDR since 1975.

Population: **6.5 million**	Human Development Index: **139 out of 189**
Income Level: **Lower middle**	Chronic malnutrition: **35.6% of children between 6-59 months**

In Numbers

US$ 1.58 million six-month (Sept 2019 – Feb 2020) net funding requirements

137.088 mt of food assistance distributed

24,484 people assisted

50% 50%

Operational Updates

- Flood update: During 29 August – 2 September 2019, heavy rainfall from Tropical Storm PODUL and Tropical Depression KAJIKI resulted in widespread flooding being reported in six provinces in southern Lao PDR (Khammouane, Attapeu, Saravan, Sekong, Savannakhet and Champasack Provinces). As of 9 September 2019, an estimated 397,000 people have been affected with 88,000 people displaced and 14 people have died. WFP is providing logistics support for the distribution of 400 mt of rice from the ASEAN Plus Three Emergency Rice Reserve (APTERR) to the affected area. As of 10 September 2019, no official request for assistance from the Government has been received by the UN Country Team, however, WFP is closely monitoring the situation and is ready to respond.
- WFP conducted an emergency food security assessment aimed to provide an overview of the humanitarian situation and risks to food security in northern provinces that have been affected by drought, rodent plagues and flash flooding during the past months. Findings are due to be released mid-September.
- WFP and the Lao Red Cross distributed 116.65 mt of rice and 8.43 mt of canned fish to the 5,395 people in Sanamxay district of the Southern Attapeu province who were hit by the floods of 2018.
- To ensure food security during the lean season, community rice banks have been established in two districts (Kaleum in Sekong Province and Sanamxay in Attapeu Province) of Southern Laos. 28 rice storage facilities have been built out of the planned 40. Food distribution is scheduled for the beginning of September, or as soon as the villages are accessible by road.
- WFP and the Ministry of Labour and Social Welfare co-chaired a Logistics Cluster Preparedness workshop in Vientiane. The workshop agreed upon focus areas for a desktop simulation to further evaluate priority tools, infrastructure and trainings needed to address gaps in emergency logistics.

Contact info: ildiko.hamossohlo@wfp.org / Communications Specialist
Country Director: Jan Delbaere
Further information: www.wfp.org/countries/lao-peoples-democratic-republic

WFP Country Strategy

GENDER MARKER 2A

Country Strategic Plan (2017-2021)

Total Requirement (in USD)	Allocated Contributions (in USD)	Sept 2019 – Feb 2020 Net Funding Requirements (in USD)
78.72 m	49.21 m	1.58 m

Strategic Result 1: Everyone has access to food

Strategic Outcome 1: Schoolchildren in remote rural areas have sustainable access to food by 2021.
Focus area: *Root causes*

Activities:

- Provide policy support, technical assistance and transfer of capacities
- Accelerate the implementation of the Government's plan of action of the school meals programme
- Support a national process for community and Government hand-over of the schools.

Strategic Result 2: No one suffers from malnutrition

Strategic Outcome 2: Stunting levels among children under 2 in provinces with high levels of malnutrition meet national levels by 2025.
Focus area: *Root causes*

Activities:

- Provide technical assistance for evidence-based policy dialogue
- Stimulate access to local specialized nutritious food for children aged 6 to 23 months
- Develop a social behaviour change communication and establish farmer nutrition schools.

Strategic Result 4: Food systems are sustainable

Strategic Outcome 3: Vulnerable households in climate-sensitive districts are more resilient to seasonal and long-term shocks and stresses.
Focus area: *Resilience*

Activities:

- Build community resilience through the creation of productive assets and sustainable livelihood opportunities.

Strategic Result 5: Developing countries have strengthened capacities to implement the SDGs

Strategic Outcome 4: National and local governance institutions are strengthened to improve service delivery, especially in hard-to-reach areas, by 2025.
Focus area: *Root causes*

Activities:

- Invest in national capacity for food and nutrition security governance
- Enable communities to lead and own their food and nutrition security solutions
- Enhance government capacity at all levels to prepare for and efficiently respond to natural disasters.

Operational Updates (continued)

- WFP held a Training of Trainers for the assembly of Mobile Storage Units (MSU) in Vientiane. 24 people participated from the Ministry of Labour and Social Welfare, Lao Military, Lao Red Cross and WFP. WFP also provided two MSUs in support of the government's prepositioning strategy for rapid temporary relief item storage or shelter following disasters. Further trainings will be organised in the provinces.
- To improve communities' resilience and raise their awareness of positive nutrition practices, WFP trained 50 people from 10 villages in Luang Namtha Province to process food and animal feed and use bio-fertilizers.
- WFP held an Agriculture for Nutrition Training of Trainers to build facilitation skills among district government technical officers. The aim is that all 12 district trainer teams will transfer their skills to facilitators in the villages targeted in 2019 and 2020, in support of activities in the Farmer Nutrition Schools programme.

Story from the field

During the Emergency Rapid Assessment in Oudomxay Province, we talked to Lar, aged 50, who is one of the poorest in her ethnic Khmu community of Kangkok Village in Xay District. Lar has seven children who she is raising alone. Her rice field is on a mountain slope and is her only source of income. In 2017, severe drought meant the family had no rice to eat or sell in 2018. This year, rats ate all her rice stocks. The family is often hungry and relies on tubers that they scavenge in the forest. Last year, Lar borrowed money to buy rice, but this year no one in the village had any to spare and she can't reach the district capital in the rainy season on the dirt roads.

Donors

USA, Australia, Japan, France, Russia, Global Agriculture and Food Security Programme, Government of Lao PDR, Private Donors

Annex A8: Media information of Flash flood in Nghe An on 11 Three killed as prolonged rains ravage Vietnam province

By **Nguyen Quy, Nguyen Hai** October 17, 2019 | 07:20 pm GMT+7

People travel on a flooded street in Vinh, Nghe An Province, October 17, 2019. Photo by VnExpress/Thang Nguyen.

Annex A9: Flash floods and lightning that came with torrential rains in the central province of Nghe An this week have left three people dead.

A 32-year-old man was struck by lightning on Wednesday while a 53-year-old man and a two-year-old boy were swept away by floods on Wednesday and Thursday.

A group of secondary school students were injured and hospitalized after being struck by lightning on the way to school on Wednesday.

Multiple roads in Vinh, the capital of Nghe An, were submerged by 0.5 meters, disrupting life for many families. Vinh received rainfall of 359mm in less than two days as of early Wednesday. Rainfall of 180 mm a day is considered heavy.

"I have lived here for 15 years and have not witnessed such serious flooding," said Nguyen Quoc Thang, head of the urban management unit in Vinh.

One of the town's three major pumps, which is designed to alleviate flooding, was not operational after rainwater damaged its engine, Thang said.

The other two pumps have been working around the clock, but could not lower the water level quickly enough due to continuous downpours from Monday, he said.

Heavy rains also flooded and damaged more than 5,000 houses and over 2,800 hectares of rice crops, local authorities said.

The nearby Ha Tinh, Binh Dinh, Phu Yen and Quang Binh Provinces have also suffered prolonged downpours due to a cold spell since Wednesday.

The National Center for Hydro-Meteorological Forecasting warned heavy rain in central Vietnam will continue until Saturday.

Natural disasters, mostly floods, storms and landslides, killed 181 people, left 37 others missing and caused losses of around VND20 trillion ($858 million) in Vietnam last year

WEEKLY UPDATE ON ASEAN PLUS THREE FOOD SECURITY RELATED INFORMATION

No. 143

6 - 12 November 2019

Indonesia

Volcanic ash rain hit several villages located on the slope of Mount Merapi. Mount Merapi in Central Java spewed volcanic ash on 9 November 2019, bringing down mild ash rain and causing effects to those nearby villages.

The eruption occurred at 6:21 a.m. (local time) with an ash column to a height of 1,500 meters and a duration of about 160 seconds.

The National Disaster and Mitigation Agency advised residents to wear face masks when they are outside and stay clear of the areas within a 3-kilometre radius of the peak of Merapi to avoid any possible danger.

Source: The Jakarta Post. (2019, Nov 9). *Mount Merapi spews hot ash.*

Philippines

A magnitude 5.5 earthquake rocked Quezon province. According to the Philippine Institute of Volcanology and Seismology (PHIVOLCS), the earthquake was felt around 4:52 a.m. (local time) and traced 42 kilometres northeast of Jumalig town in Quezon province at a depth of 7 kilometres.

The tremor was caused by the movement of an active fault in the area. The PHIVOLCS expected that the aftershocks would be likely to occur.

However, there was no report of damage or casualty.

Source: Manila Bulletin. (2019, Nov 7). *5.5-magnitude quake shakes Quezon.*

At least six people died during the onslaught of typhoon Nakri. Former tropical storm Nakri strengthened into a typhoon in the South China Sea on 8 November 2019, bringing strong winds, high waves and heavy rain to parts of Luzon island.

According to the National Disaster Risk Reduction and Management Council (NDRRMC), at least 6 people reported dead and nearly 85,000 people affected while approximately 5,720 people evacuated to relief centres. Around 7 houses, 56 roads and 10 bridges across the island were damaged.

Source: Flood List. (2019, Nov 9). *Philippines – Rain From Typhoon 'Nakri' Causes Deadly Floods and Landslides.*

Viet Nam

Storm Nakri was downgraded to a tropical depression. Yet, the rain was expected to continue affect Viet Nam. The central region and central highlands tended to face torrential rains for the next couple of days.

Khanh Hoa province was the hardest-hit area. About 350 hectares of rice and cash crops were damaged while 10 cages of aquaculture affected. The storm also caused landslides along the roads.

As of 11 November 2019, electricity was restored to 53 out of 112 communes which suffered blackouts the previous day.

The localities were requested to inspect the areas at risk of flash floods and landslides and be proactive in evacuating people and adopt safety measures.

ANNEX B: MRCFFGS Operation Output Product Descriptions

Annex B1: FFGS' Products descriptions

MRCFFG Operational Output Product Descriptions				
Label	**Definition**	**Format**	**Updated**	**Description**
HE Sat	Hydroestimator Satellite Precipitation	Images	Hourly	The images display gridded hourly, 3-hourly, 6-hourly and 24-hourly totals of precipitation (mm) ending on the current hour as estimated in real-time from geostationary satellites using the Hydroestimator algorithm. The satellite rainfall estimates are provided on a grid having approximately 10x10 km resolution which is displayed over a background of MRCFFG sub-basin boundaries. The HE Sat data products are updated every hour and reflect rainfall accumulations ending on the current product hour.
				SAT 01-hr: Total of precipitation as estimated by the Hydroestimator over the last hour ending on the current product hour. (mm/1hr)
				SAT 03-hr: Total of precipitation as estimated by the Hydroestimator over the last 3 hours ending on the current product hour. (mm/3hr)
				SAT 06-hr: Total of precipitation as estimated by the Hydroestimator over the last 6 hours ending on the current product hour. (mm/6hr)

				SAT 24-hr: Total of precipitation as estimated by the Hydroestimator over the last 24 hours ending on the current product hour. (mm/24hr)
.	.	.	.	.
Merged MAP	Mean Areal Precipitation	Text & Images	Hourly	Text tables and images of hourly, 3-hourly, 6-hourly and 24-hourly totals of mean areal precipitation (mm) for each MRCFFG catchment. It includes real-time or climatological bias adjustment of the real-time satellite rainfall and substitution of interpolated precipitation of 6-hourly raingauge data for sub-basins with no available satellite information (either by unavailability or masking). The Merged MAP data products are updated every hour and reflect accumulations of basin-average precipitation of a given duration ending on the current product hour.
				MAP 01-hr: Total mean areal precipitation estimated over the last hour ending on the current product hour. (mm/1hr)
				MAP 03-hr: Total mean areal precipitation estimated over the last 3 hours ending on the current product hour. (mm/3hr)
				MAP 06-hr: Total mean areal precipitation estimated over the last 6 hours ending on the current product hour. (mm/6hr)
				MAP 24-hr: Total mean areal precipitation estimated over the last 24 hours ending on the current product hour. (mm/24hr)

.	.	.	.	.
ASM	Average Soil Moisture	Text & Images	00, 06, 12 & 18 UTC	Text tables and images provide soil water saturation fraction (dimensionless ratio of contents over capacity) for the upper zone (down to 20-30 cm depth) of the Sacramento Soil Moisture Accounting Model for each of the MRCFFG sub-basins. The products are updated every 6 hours at the model processing hour (i.e. 00, 06, 12 and 18 UTC).
				ASM 06-hr: Average soil water saturation at most recent model processing hour. (fraction of soil capacity in the upper zone)
.	.	.	.	.
FFG	Flash Flood Guidance	Text & Images	00, 06, 12 & 18 UTC	Text tables and images of hourly, 3-hourly and 6-hourly flash flood guidance (mm) for each MRCFFG sub-basin are provided. The FFG value indicates the total volume of rainfall over the given duration which is just enough to cause bankfull flow in the draining stream outlet. Consequently, rainfall volumes of the same duration that are greater than the FFG value indicate a likelihood of overbank flows at the draining stream outlet. Each of the FFG products is updated at every model processing hour (00, 06, 12 and 18 UTC). **This product is appropriate to use in real time with nowcasts or forecasts of rainfall and other local information to estimate the risk of**

				flash flooding in the MRCFFG sub-basins.
				FFG 01-hr: Required precipitation over the next hour following the most recent (current) model processing hour to cause bankfull flow. (mm/1hr)
				FFG 03-hr: Required precipitation over the next 3 hours following the most recent (current) model processing hour to cause bankfull flow. (mm/3hr)
				FFG 06-hr: Required precipitation over the next 6 hours following the most recent (current) model processing hour to cause bankfull flow. (mm/6hr)
				Prev FFG 01-hr: Required precipitation over the hour following the previous model processing hour to cause bankfull flow. (mm/1hr)
				Prev FFG 03-hr: Required precipitation over the 3 hours following the previous model processing hour to cause bankfull flow. (mm/3hr)
				Prev FFG 06-hr: Required precipitation over the 6 hours following the previous model processing hour to cause bankfull flow. (mm/6hr)

.	.	.	.	.
PFFT	Persistence Flash Flood Threat	Text & Images	00, 06, 12 & 18 UTC	PFFT products include text tables and images of hourly, 3-hourly and 6-hourly flash flood threat (mm) for each MRCFFG catchment. The values indicate the difference of recent persisted merged estimates of mean areal rainfall of the given duration and the corresponding current FFG of the same duration for a given MRCFFG sub-basin. The last 1-hour, 3-hour and 6-hour durations of MAP are persisted and considered with current corresponding FFG in the computation of PFFT.
				For example, the 6-hr PFFT at 12:00 UTC = 06-hr MAP from 12:00 UTC - 06-hr FFG from 12:00 UTC
				In the images, an approximate measure of uncertainty in the PFFT estimates is indicated by the ranges in the color scale (with yellow indicating the range of values that are unlikely to be of concern for flash flooding and with orange and red indicating progressively higher risk of flooding for the sub-basin of interest). The hourly, 3-hourly and 6-hourly PFFT products are updated at model processing hours (00, 06, 12, 18 UTC). **Note that this set of products uses a crude rainfall forecast and probably contains large uncertainties. PFFT is offered as a baseline product that**

				must be carefully evaluated by the forecaster in real-time.
				PFFT 01-hr: Difference of 01-hr FFG for current model processing hour and current 01-hr MAP persisted for the next 1 hour. (mm/1hr)
				PFFT 03-hr: Difference of 03-hr FFG for current model processing hour and current 03-hr MAP persisted for the next 3 hours. (mm/3hr)
				PFFT 06-hr: Difference of 06-hr FFG for current model processing hour and current 06-hr MAP persisted for the next 6 hours. (mm/6hr)
.	.	.	.	.
FFT	Flash Flood Threat	Text & Images	1, 3 and 6 hours after previous model processing hour	FFT products include text tables and images of hourly, 3-hourly and 6-hourly flash flood threat (mm) for each MRCFFG catchment. The values indicate the difference of the observed mean areal rainfall of the given duration and the corresponding past FFG of the same duration for a given MRCFFG sub-basin. The last 1-hour, 3-hour and 6-hour durations of FFG are considered with current corresponding MAP in the computation of FFT.

				For example, the 06-hr FFT at 12:00 UTC = 06-hr MAP from 12:00 UTC - 06-hr FFG from 6:00 UTC
				The most recent FFT product for each time-scale is provided in the Baseline Threat Product table and displayed with the MAP and FFG products that were used in the respective calculation. In the images, an approximate measure of uncertainty in the FFT estimates is indicated by the ranges in the color scale (with yellow indicating the range of values that are unlikely to be of concern for flash flooding and with orange and red indicating progressively higher risk of flooding for the sub-basin of interest). The hourly, 3-hourly and 6-hourly FFT products are respectively updated at 1, 3, and 6 hours after the preceding model processing hour. FFT provides the forecaster with an idea of likely regions of imminent flash flood threats. **Note that this set of products concerns the past and may not be appropriate to use for real-time warning. FFT is offered as a baseline product that must be carefully evaluated by the forecaster in real-time.**
				FFT 01-hr: Difference of 01-hr FFG from a previous model processing hour and 01-hr MAP observed over the following 1 hour. (mm/1hr)

				FFT 03-hr: Difference of 03-hr FFG from a previous model processing hour and 03-hr MAP observed over the following 3 hours. (mm/3hr)
				FFT 06-hr: Difference of 06-hr FFG from a previous model processing hour and 06-hr MAP observed over the following 6 hours. (mm/6hr)

Annex B2: Template of FFG bulletin (word format)

Bulletin of Flash Flood Guidance On 21 July 2017 at 00:00 UTC (07:00AM Local time)

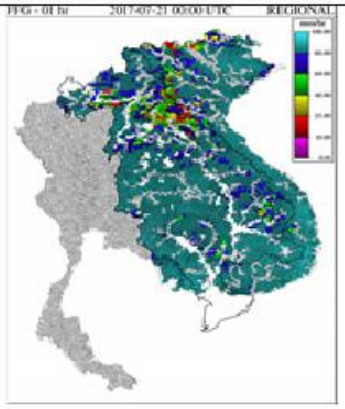


Figure 1: 01 hourly of Flash Flood Guidance (FFG) values on 21 July 2017 at 00:00 UTC (07:00 local time).
01 hourly shows high-risk flash flood occurrence at Laos, Thailand and Vietnam.

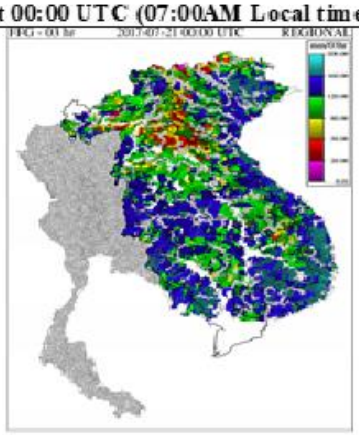


Figure 2: 03 hourly Flash Flood Guidance (FFG) on 21 July 2017 at 00:00 UTC (07:00 local time).
03 hourly shows high-risk flash flood occurrence at Laos, Thailand, Cambodia and Vietnam.

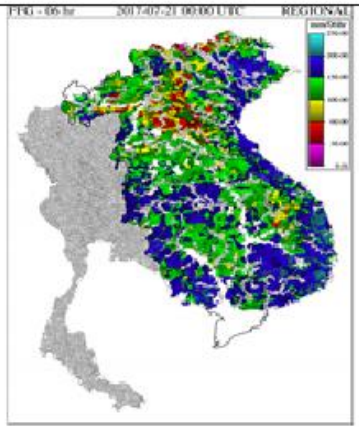


Figure 3: 06 hourly Flash Flood Guidance 21 July 2017 at 00:00 UTC (07:00 local time).

06 hourly shows high-risk flash flood occurrence at Laos, Thailand, Cambodia and Vietnam.

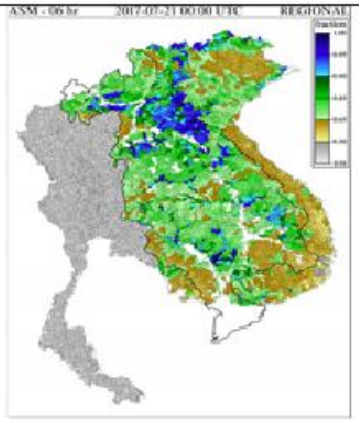


Figure 4: 06 hourly Average Soil Moisture (ASM) condition (upper soil zone) up to 21 July 2017 at 00:00 UTC (07:00 local time).
06 hourly ASM shows that the soil moistures at some areas of Lower Mekong Basin.

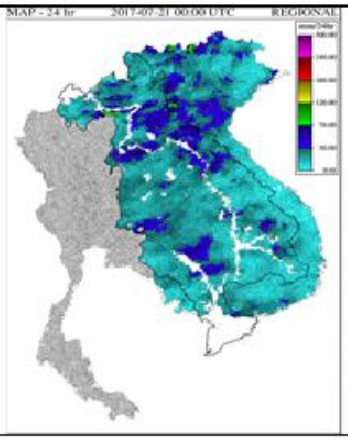


Figure 5: 24 hourly Mean Areal Precipitation (MAP) from 00:00 UTC on 20 June 2017 to 00:00 UTC (07:00 local time) on 21 July 2017.

24 hourly MAP shows that there is heavy rain occurred at some areas in Lower Mekong Basin and north of Vietnam.

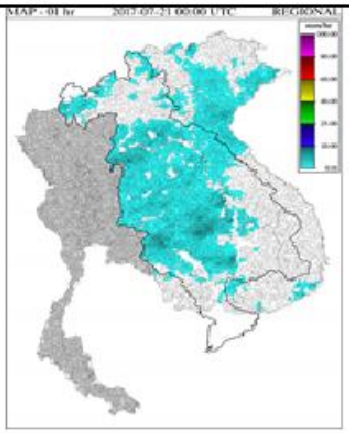
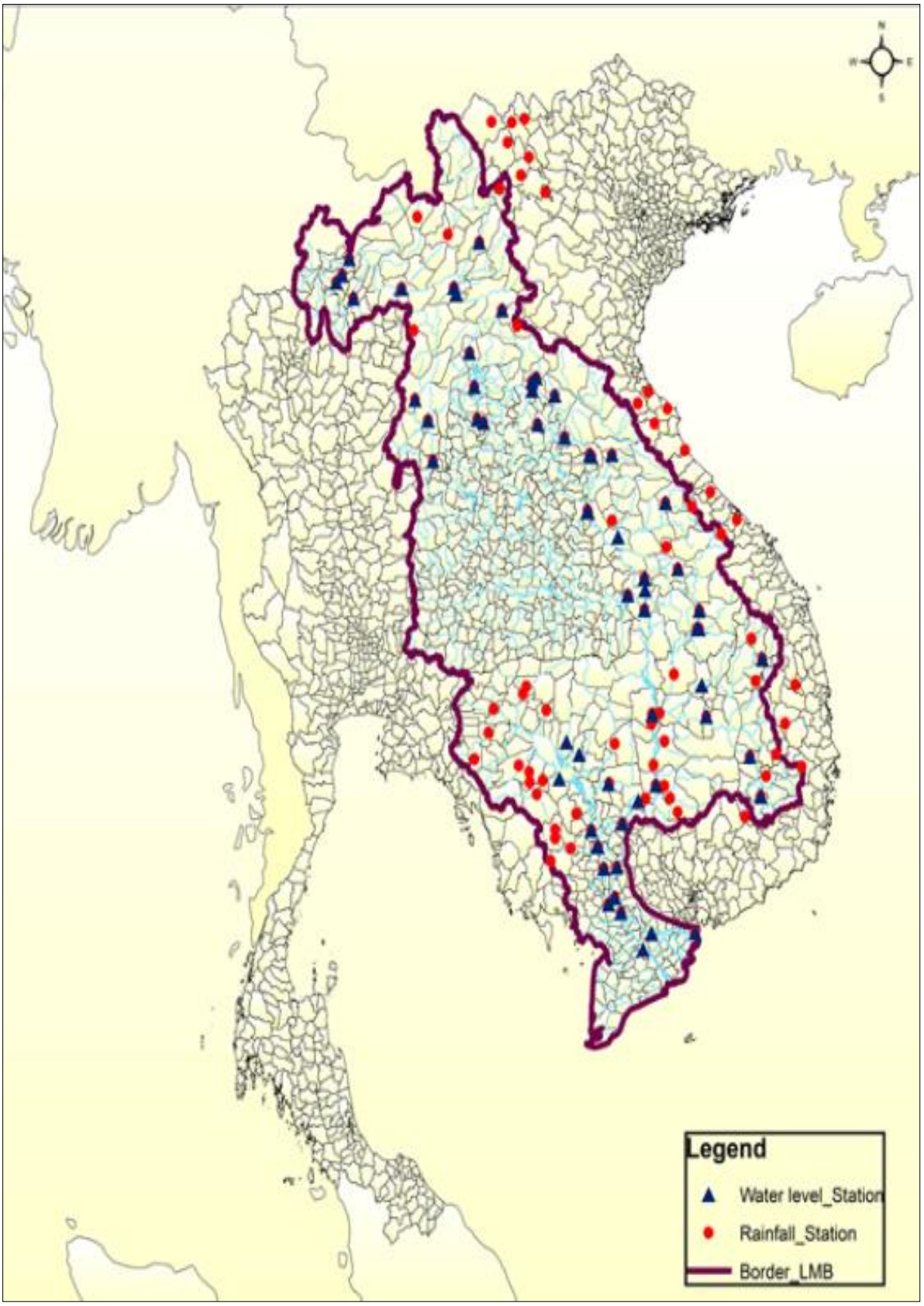


Figure 6: The last 01 hour of Mean Areal Precipitation (MAP) at 00:00 UTC (07: 00 local time) on 21 July 2017.

01 hourly MAP shows that there is heavy rain occurred in Lower Mekong Basin.

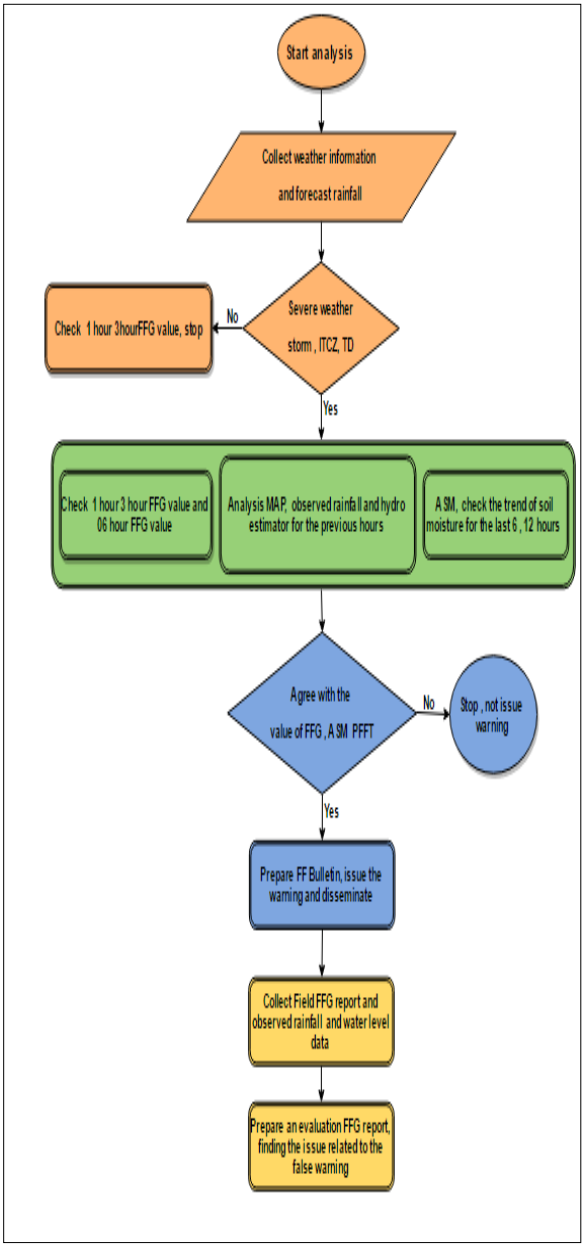
ANNEX C: Hydmet database and daily operation of MRCFFGS

Annex C1: The map of rainfall and water level stations database network



Annex C2: Daily Operation of The MRC FFG System

Color indicated in the work flow	Time frame for process the work	Work activities
	From 7:00 to 7:30 for morning operation From 13:00 to 13: 30 for afternoon operation	Collect the information from web site www.tropicalstormrisk.com; https://sharaku.eorc.jaxa.jp/GSMaP/index.htm; https://www.windy.com/vi/-M%C6%B0a-s%C3%A9t-rain?rain,51.383,0.517,5 and rainfall forecast from NOAA, and do analysis weather situation
	From 7:30 to 8:10 for morning operation From 13:30 to 14:00 for afternoon operation	Process 1,3,6-hour FFG according to the guideline for processing MRC FFG System Calculate the accumulated rainfall for observed (ground) rainfall which available in Hydmet database, and compare with the accumulate MAP and accumulate Global Hydro -Estimator
	From 8:10 to 8:30 for morning operation From 14:00 to 14:30 for afternoon operation	Prepare the Flash Flood waring text in word format and table in excel, map - KMZ of the warning by areas, send it to IT staff of RFMMC to upload to web site.
	With week after the issue the warning. The evaluation report should be kept for review and add the additional of data received for NLAs at the end of flood season	Contact to the national line agencies or the national FFG operator to request the flash flood information or also collect flash flood information from the online newspaper. Prepare the FFG evaluation report according to the guideline of FFG evaluation report



Annex D: Communication between RFDMC and HRC to solve the errors of MRCFFGS and announcement those problems to MCs during maintained the system in flood season 2019.

Dear Anh,

Thank you for bringing this to our attention. HRC identified the cause of the WRF interruption as an unmanaged storage accumulation of WRF output that lead to a drive filling. We have corrected the problem and see that the next model execution is proceeding normally.

Best regards,

Cristopher Spencer
Hydrologic Research Center
11440 West Bernardo Court, Suite 375
San Diego, CA 92127
+1-858-798-9440
cspencer@hrcwater.org
http://www.hrcwater.org

From: Nguyen Quoc Anh [mailto:Anh@mrcmekong.org]
Sent: Saturday, June 1, 2019 8:24 PM
To: Jason Sperfslage <jsperfslage@hrcwater.org>; 'Cristopher Spencer' <cspencer@hrcwater.org>; Sokong Ann <sokong@mrcmekong.org>
Cc: Konstantine Georgakakos <kgeorgakakos@hrcwater.org>; Son Lam Hung <son@mrcmekong.org>; Kunthea NUON <kunthea@mrcmekong.org>
Subject: WRF not available on MRCFFG console.

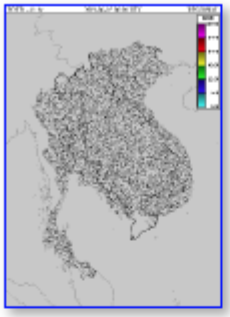
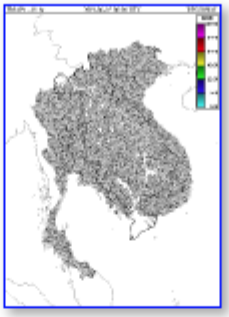
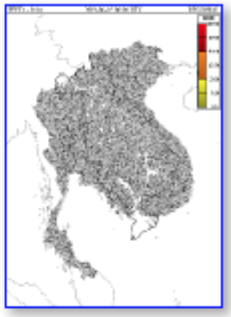
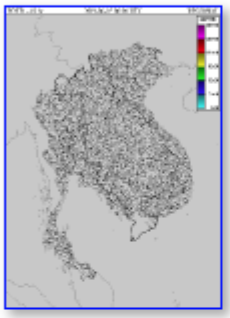
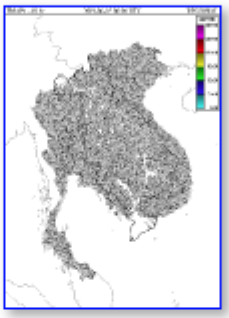
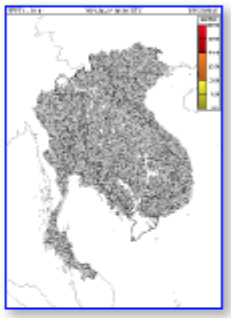
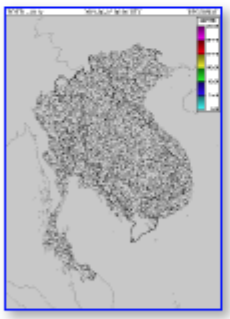
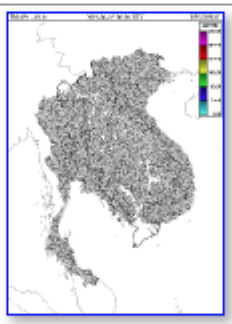
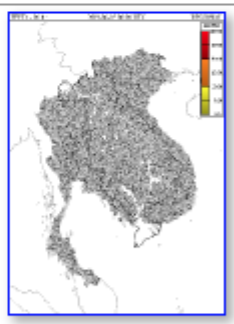
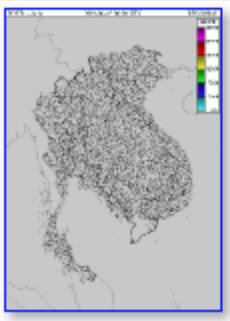
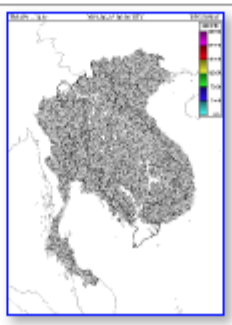
Dear Jason, Cris and Sokong Ann,

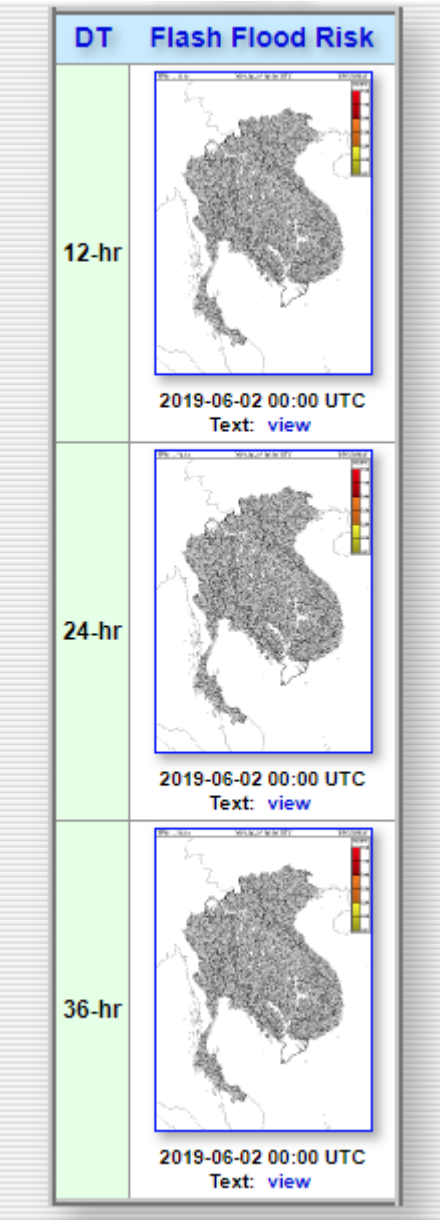
During the operation task on Flash Flood Guidance from MRCFFG System on 02 June 2019, the products of WRF at 00: 00 UTC were not had value on console interface as figure below. Please help us to check. Thank you very much.

Best regards,

Nguyen Quoc Anh

Product Console - Model Forecast Products

DT	WRF Forecast	FMAP	FFFT
01-hr	 2019-06-02 00:00 UTC	 2019-06-02 00:00 UTC Text: view	 2019-06-02 00:00 UTC Text: view
03-hr	 2019-06-02 00:00 UTC	 2019-06-02 00:00 UTC Text: view	 2019-06-02 00:00 UTC Text: view
06-hr	 2019-06-02 00:00 UTC	 2019-06-02 00:00 UTC Text: view	 2019-06-02 00:00 UTC Text: view
24-hr	 2019-06-02 00:00 UTC	 2019-06-02 00:00 UTC Text: view	



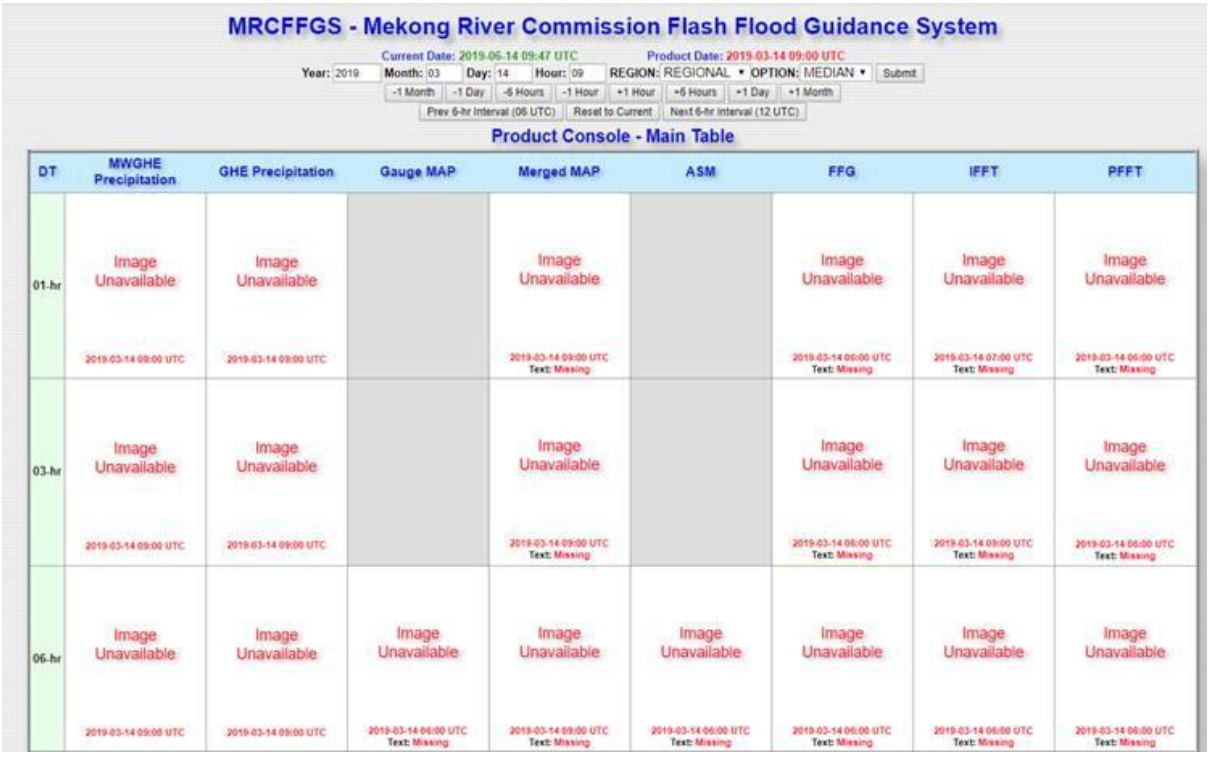
Dear Dr., Kosta,

Hope this email finds you are well.

Since the MRCFFGS was reinstalled it has been running very smooth and very useful for the forecasters. As you know that, the history products of the MRCFFGS are very important for forecasters while they are making the forecasting operation, but on the MRCFFGS console interface those products are not available (please figures as below). Therefore, we would like to suggest that you please support us to update those data on the console interface. And, also please guide our IT to access the server (FTP) to back up the products. He will back up as weekly or monthly from now on. Thank you very much.

Best regards,

Nguyen Quoc Anh.



Dear Sokong,

In the latest version of the MRCFFG System, the XYZ gridded files are no longer generated and have been replaced with a newer file in the GRD format. The change to a GRD format was made for many reasons but the most important are that (a) GRD is an industry-standard format that can be ingested into 3rd party programs, (b) the GRD files are much smaller, (c) GRD files can be produced much faster, and (d) GRD they support the newly added Mapserver Interface.

You can find the new GRD files in the following locations (using 2019-07-05 for an example day)…

Microwave-adjusted Global HydroEstimator: */MRCFFG/OPERATIONAL/DATA/EXPORTS/REGIONAL/2019/07/15/MWGHE_GRD*

Global HydroEstimator Preciptation: */MRCFFG/OPERATIONAL/DATA/EXPORTS/REGIONAL/2019/07/15/GHE_GRD*

MRCWRF Forecast Precipitation: */MRCFFG/OPERATIONAL/DATA/EXPORTS/REGIONAL/2019/07/15/FCST1_GRD*

It is important to note that these new files are only available for the MRCFFG "Regional" view including all member states and not available for individual countries. Please take a look at this new file format and let us know if you have any difficulty working with the updated file format. We are here to provide assistance if you have any questions.

Best regards,

Cristopher Spencer
Hydrologic Research Center
11440 West Bernardo Court, Suite 375
San Diego, CA 92127
+1-858-798-9440
cspencer@hrcwater.org
http://www.hrcwater.org

From: Sokong Ann [mailto:sokong@mrcmekong.org]
Sent: Friday, July 12, 2019 7:22 PM
To: 'Cris Spencer' <cspencer@hrcwater.org>
Cc: Jason Sperfslage <jsperfslage@hrcwater.org>; Konstantine Georgakakos <kgeorgakakos@hrcwater.org>; Nguyen Quoc Anh <Anh@mrcmekong.org>; Son Lam Hung <son@mrcmekong.org>; Sameng Preap <sameng@mrcmekong.org>; Sothea Khem <khem@mrcmekong.org>; Kunthea NUON

<kunthea@mrcmekong.org>
Subject: RE: MRCFFGS Administrative Access

Dear Cris,

After I have go through the system, I found that I can not find the HydroEstimator Raw file in the system. As I learned that in the old system we have this file. Could you please let us know if this file is still exist or where the file is. Thank you so much for your kind support.

Regard,

Sokong

From: Nguyen Quoc Anh <Anh@mrcmekong.org>
Sent: Sunday, June 30, 2019 07:34
To: Konstantine Georgakakos <kgeorgakakos@hrcwater.org>; Sokong Ann <sokong@mrcmekong.org>
Cc: 'Cris Spencer' <cspencer@hrcwater.org>; Jason Sperfslage <jsperfslage@hrcwater.org>
Subject: RE: MRCFFGS Administrative Access

Dear Kosta,
Thank you very much for your email. I received and will keep it as confidential.
Best regards,
Nguyen Quoc Anh.

From: Konstantine Georgakakos <kgeorgakakos@hrcwater.org>
Sent: Saturday, June 29, 2019 2:43 AM
To: Nguyen Quoc Anh <Anh@mrcmekong.org>; Sokong Ann <sokong@mrcmekong.org>
Cc: 'Cris Spencer' <cspencer@hrcwater.org>; Jason Sperfslage <jsperfslage@hrcwater.org>
Subject: MRCFFGS Administrative Access
Importance: High

Dear Nguyen Anh and Sokong Ann :

As you are the representative of the MRCFFG Regional Center Administration and IT for the MRC flash flood guidance system implementation in the region, I write to provide officially on behalf of the Hydrologic Research Center the credentials for:

***a*.** The MRCFFG Server "root" administrative user access; and ***b*.** The MRCFFG System "mrcffg" operational system user access.

These are shown below. Please safeguard those as they **should not be distributed to third parties** and they are provided **for the sole use** of the MRCFFG regional center IT services as necessary for the operation of the MRCFFG system installed.

Also, attached please find the detailed User Guide for the system.

Please acknowledge receipt but remove the credentials from your reply.

Thank you.

With best wishes,

Konstantine (Kosta)

Konstantine P. Georgakakos, Sc.D.
Director
HYDROLOGIC RESEARCH CENTER
11440 West Bernardo Court, Suite 375
San Diego, CA 92127, USA
Tel: +1-858-798-9440
Alternative Tel:+1-858-461-4560
Email: KGeorgakakos@hrcwater.org
http://www.hrcwater.org

Also, Adjunct Professor VIII with Scripps Institution of Oceanography, UCSD

Dear all,
We would like to inform you that, this morning we found that there is an error with FFG server, could not log-in. Now we are on processing to solve and hope that completed soon. We apologize for this inconvenience.
Thank you for your kindly cooperation.
Best regards,

Nguyen Quoc Anh

Nguyen Quoc Anh | Operation Meteorologist/Flood Forecast
MRC Regional Flood and Drought Management Centre | Phnom Penh
t: +855 -23 425 353 ext 2109| m: +855 71 437 3043 | w: mrcmekong.org | L: office location
P.O. Box 623, No. 576, National Road No. 2, Sangkat Chak Angre Krom, Khan Mean Chey, Phnom Penh 12353, Cambodia

Mekong River Commission
For Sustainable Development

Annex E: Performance achieved flash flood operation for each country in the LMB; base on analyzing MRCFFG products at RFDMC in the flood season 2019

THAILAND				
a = Hits b= False alarms c= Misses d= Correct negatives		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	4	3	7
	No	2	230	232
	Total	6	233	239
Hit rate (POD)		0.67		
False Alarm Ratio (FAR)		0.43		
False Alarm Rate (POFD)		0.01		
Threat Score (TS)		0.33		

LAO PDR				
a = Hits b= False alarms c= Misses d= Correct negatives		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	8	10	18
	No	3	230	233
	Total	11	240	251
Hit rate (POD)		0.73		
False Alarm Ratio (FAR)		0.56		
False Alarm Rate (POFD)		0.04		
Threat Score (TS)		0.48		

CAMBODIA				
a = Hits b= False alarms c= Misses d= Correct negatives		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	5	1	6
	No	1	230	231
	Total	6	231	237
Hit rate (POD)		0.833		
False Alarm Ratio (FAR)		0.167		
False Alarm Rate (POFD)		0.004		
Threat Score (TS)		0.143		

VIETNAM				
a = Hits b= False alarms c= Misses d= Correct negatives		EVENT OBSERVED		
		Yes	No	Total
EVENT FORECASTED	Yes	13	5	18
	No	4	230	234
	Total	17	235	252
Hit rate (POD)		0.76		
False Alarm Ratio (FAR)		0.28		
False Alarm Rate (POFD)		0.02		
Threat Score (TS)		0.23		