

An application of numerical weather forecast and satellite rainfall prediction to flood forecasting (Presentation on APRASAF - 15)



National Centre for Hydro-Meteorological Forecasting (NCHMF)

10 Dec 2008
Dr.Dang Ngoc Tinh

INTRODUCTION

- Flood forecasting system consists of 4 modules, such as: Real time data acquisition for observed meteorological and hydrological conditions; Forecast of meteorological conditions; Hydrologic and hydraulic models for simulation; and Updating and data assimilation.
- My presentation will focus on 3 main components of flood forecasting system:
 1. Rainfall forecast (numerical and satellite)
 2. Mike11 software
 3. Data assimilation with case study for the Red River system in Vietnam.

1. Rainfall prediction data

Numerical daily rainfall forecasts were collected for the period 15 June until 30 September 2004 from sources: HRM, JMA, ECMRWF, NOAA-USGS, TRMM .

HRM:

- For weather forecasting the National Centre for Hydro-meteorological Forecasting (NCHMF) makes use of the High-resolution Regional Model (HRM), originally developed by the Deutsche Wetter Dienst (DWD). The HRM model takes its initial and boundary conditions from the global model GME (DWD) every 3 hours from the internet. HRM runs with two resolutions:
- a coarser resolution with grid spacing 0.25° (28 km) for the domain 5°S - 35°N , 80.25° - 130.25°E) for 20 vertical layers, and
- A finer resolution with grid spacing 0.125° (14 km) for the domain 7.25° - 27°N , 97.375° - 117.25°E) for 31 vertical layers.
- With HRM forecasts on wind, temperature, humidity and rainfall are made for the next 72 hrs. The performance of the HRM model is not satisfactory yet. Monsoon patterns are well forecasted but systems from the sea are not. Since the latter produce the rainfall in the flood season the following performance pattern is observed:
- ***heavy rains are always underestimated, and***
- ***lighter rains always overestimated.***
- It is suspected that the assimilation of observations in GME for this part of the world is not optimal, so the boundary conditions delivered by GME are inadequate. It is intended to improve this by taking the boundary conditions in future from the AVN/NCEP global model, which is foreseen for late 2005.

1. Rainfall prediction data (continue)

JMA

Since 2001 also every 6 hrs weather forecasts for the next 72 hrs are obtained from JMA of Japan. This provides rainfall data at a coarser $1.25^{\circ} \times 1.25^{\circ}$ grid (140 x 140 km). Its rainfall forecasts are generally much better. Therefore, the HRM and JMA forecasts have been combined to see if this results in better flow forecasts, with calibrating coefficient $k = \text{RJMA/RHRM}$

ECMRWF

The European Centre for Medium-Range Weather Forecasts (ECMWF) delivers weather forecasts for the whole world on a grid-basis, up to 10 days ahead. The grid of the data covers the domain 16.75° - 26.25° - N, 99.75° - 108.25° E.

NOAA-USGS, TRMM

Satellite rainfall estimation, prediction:

+ NOAA-USGS satellite rainfall estimation: domain 70-110E;5-35N. This product is updated three times daily at around 9am, 1pm, and 9pm Eastern Local Time and covers a 24 hour period of accumulated precipitation.

Resolution of rainfall estimates are 0.1 by 0.1 degree and inputs include GTS station data, as well as geostationary infrared cloud top temperature fields and polar orbiting satellite precipitation estimate data from SSM/I and AMSU-B microwave sensors.

1. Rainfall prediction data (continue)

<ftp://ftp.cpc.ncep.noaa.gov/fews/S.Asia/>

+ 3-day rainfall forecasts by MM5

+ 7-day forecast GFS by AVN/NCEP.

+ TRMM (Tropical Rainfall Measure Mission) data with 3-hour cumulative rainfall, 0.25 degree space.

<ftp://trmmopen.gsfc.nasa.gov/pub/merged/mergeTRMicro/>

+ Global Satellite Mapping of Precipitation (GSMaP) with mesh size 0.1 degree, domain 60° S - 60°N., A~120km²

<http://www/gsmmap.aero.osakapu-u.ac.jp/data/V484/MVK/hourly/>

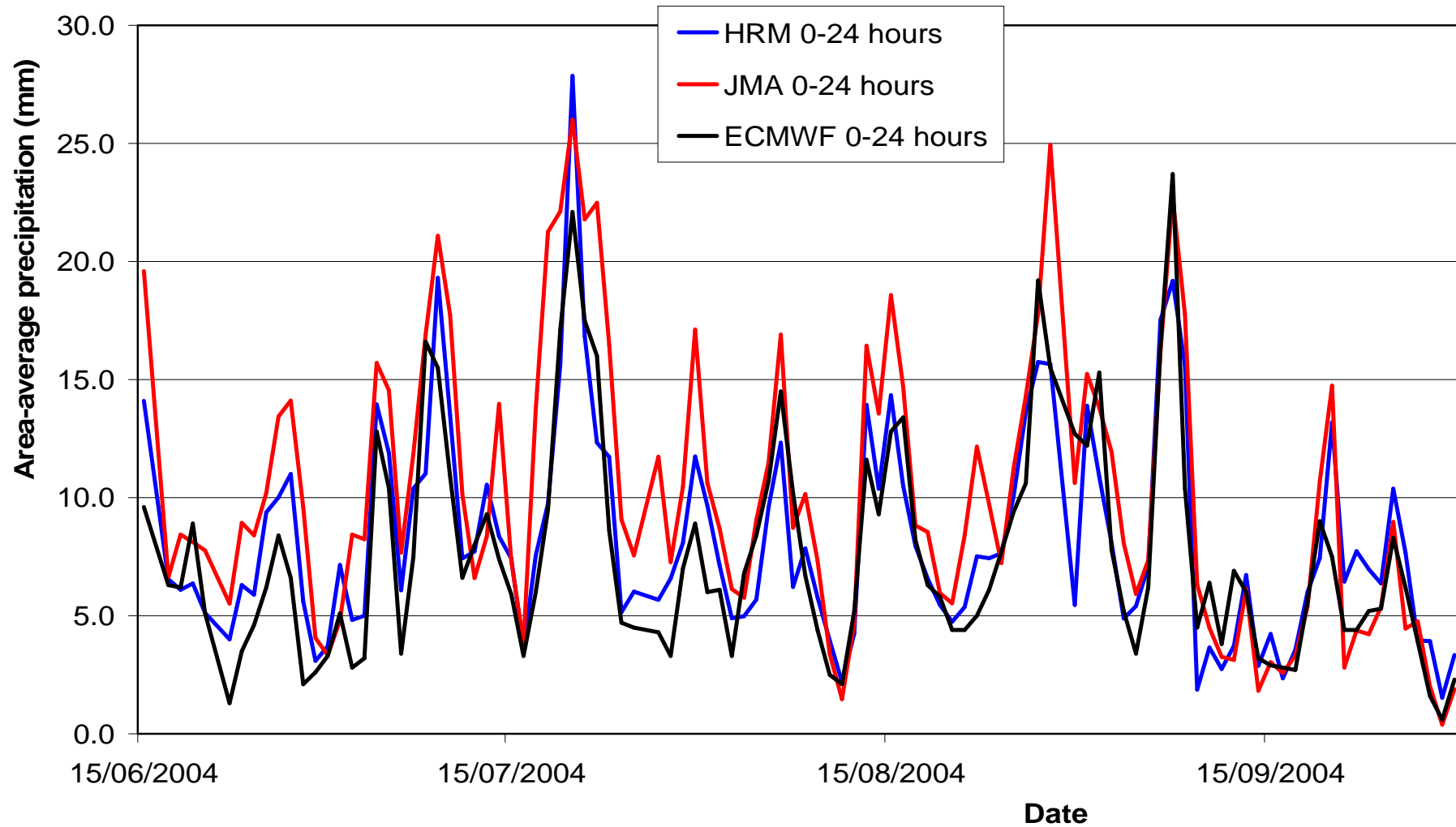
+ Satellite rainfall data QMORPH: 8 km mesh, previous 18 hours, time interval 30 minutes

http://www.cpc.ncep.noaa.gov/products/janowiak/cmorph_description.html

1. Rainfall prediction data (continue)

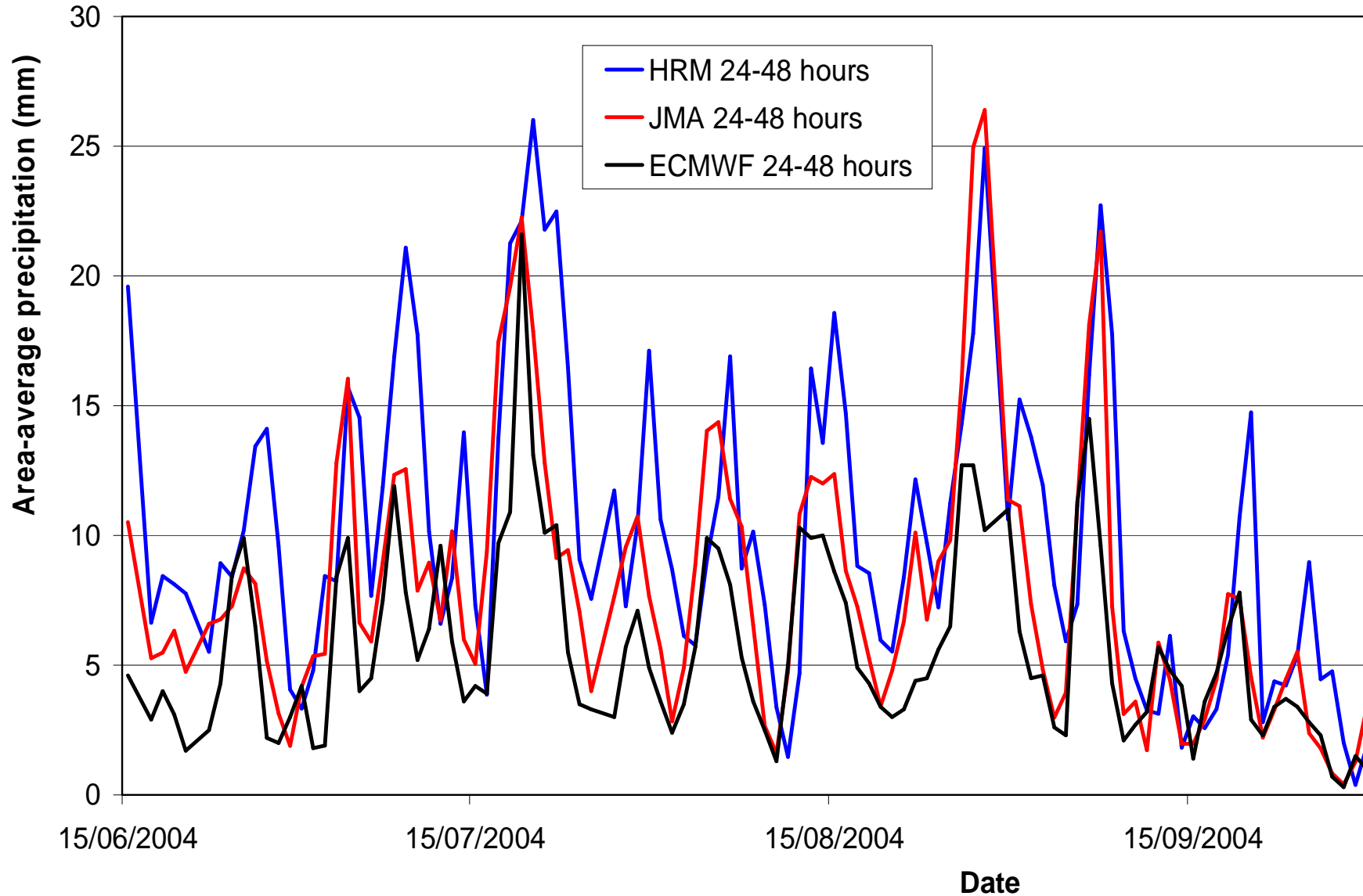
Comparison of rainfall prediction data HRM, JMA and ECMWF

The peak rainfall events seem to coincide very well, especially if one compares ECMWF with JMA.



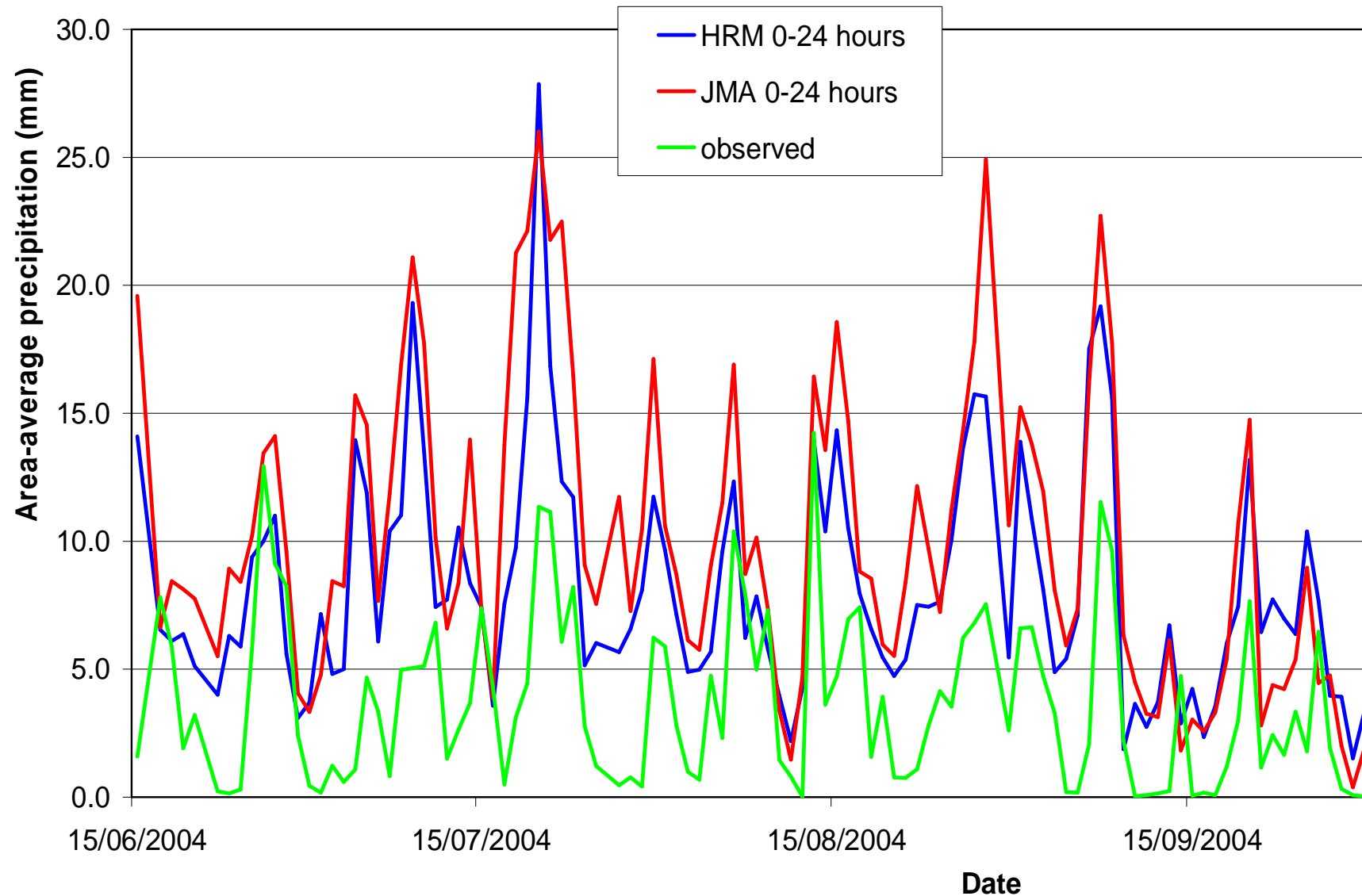
1. Rainfall prediction data (continue)

Comparison of rainfall prediction data HRM, JMA and ECMWF



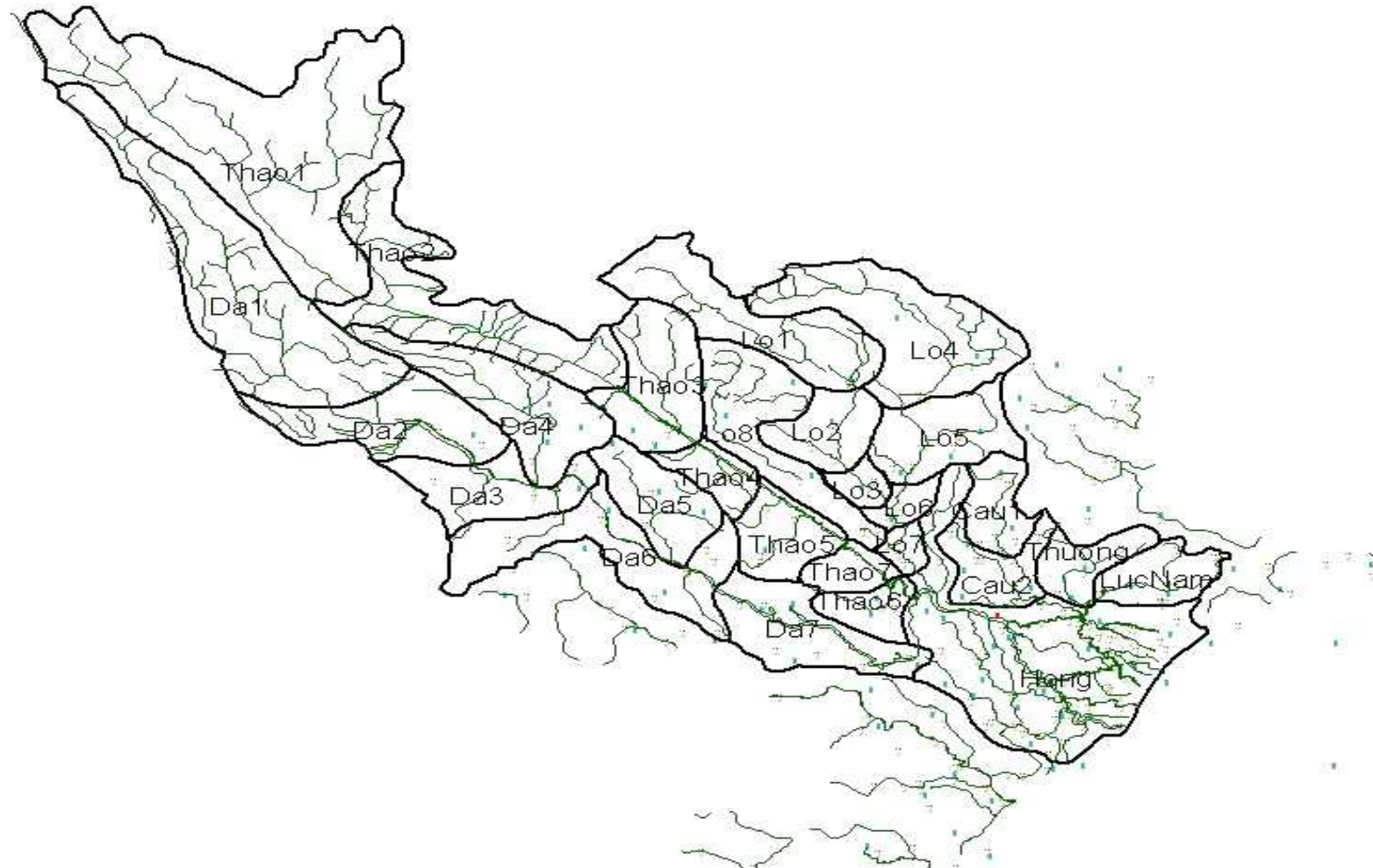
1. Rainfall prediction data (continue)

Area-average rainfall for the domain 17.5o-26.25o N, 100o-110o E (HRM and JMA) for forecasts with lead time 0-24 hours and observed area-average rainfall in the Red river basin.



2. Application of hydrological - hydraulic models

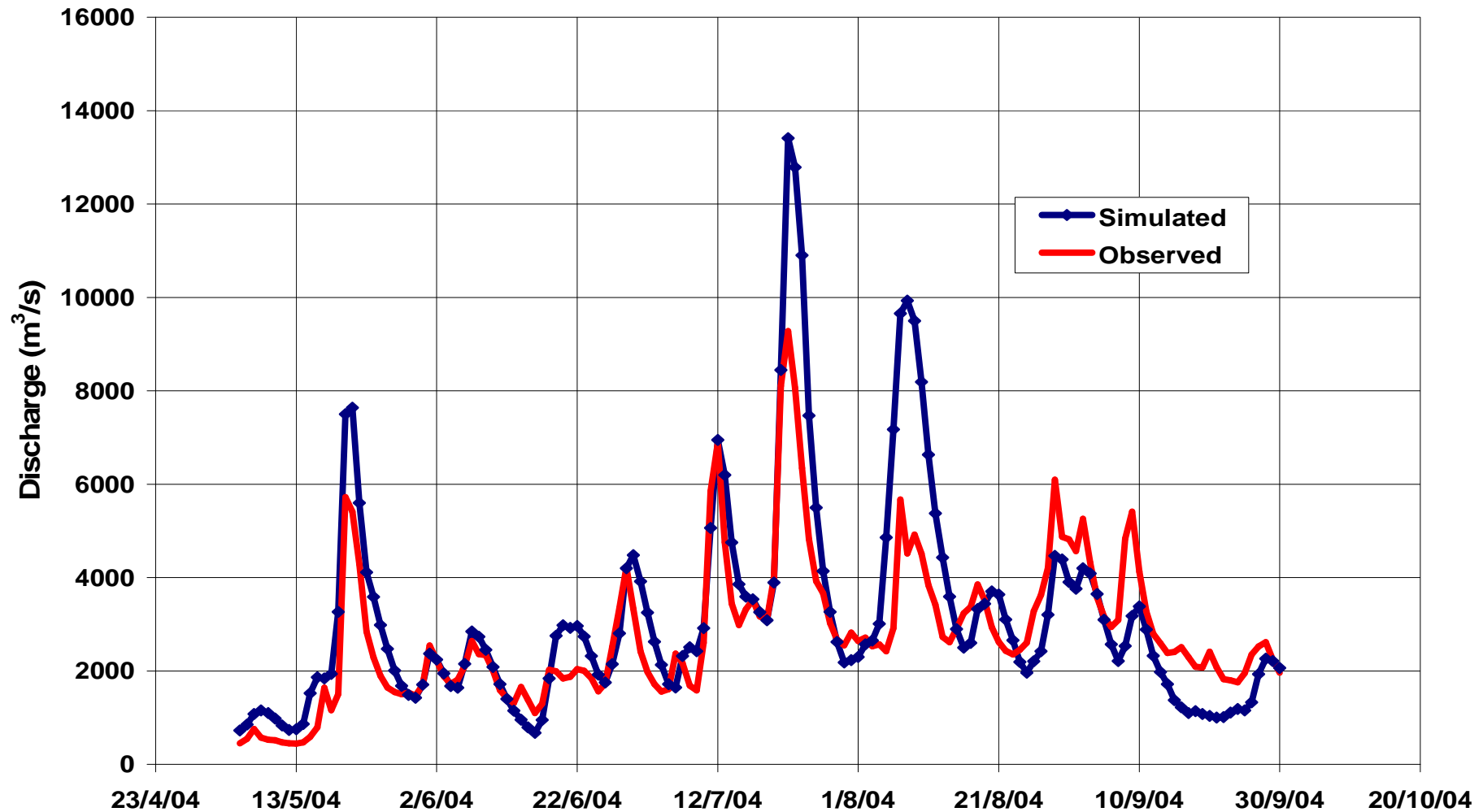
- Used NAM and hydrodynamic model Mike11 for flood forecasts at the Red river system with rainfall prediction from numerical weather forecasting products. The Red river basin with area 169000 km² divided into 27 sub-basins



2. Application of hydrological - hydraulic models

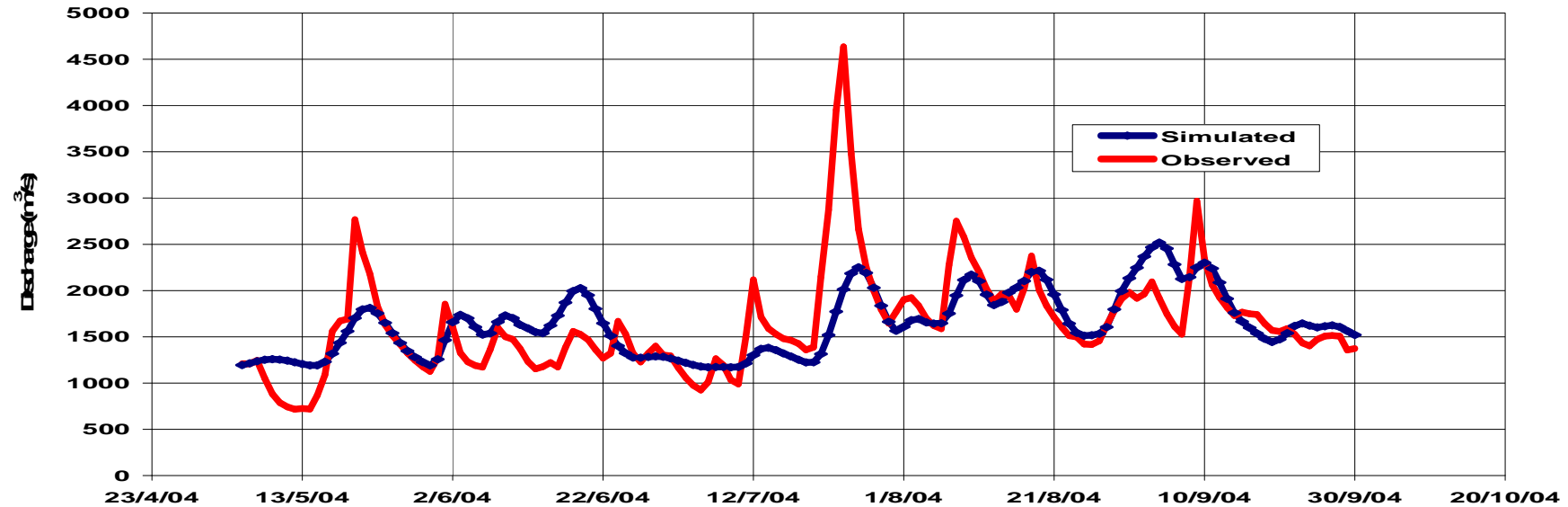
- The NAM model was calibrated with observed rainfall and discharge records of the years 2004. Runoff calculated from rainfall by NAM linked as inflow from tributaries or upper reaches or lateral flow into main stream by Muskingum routing. Flow routing in main stream was made by hydrodynamic Mike11.

Calibration of NAM-model: Da at Hoa Binh u/s

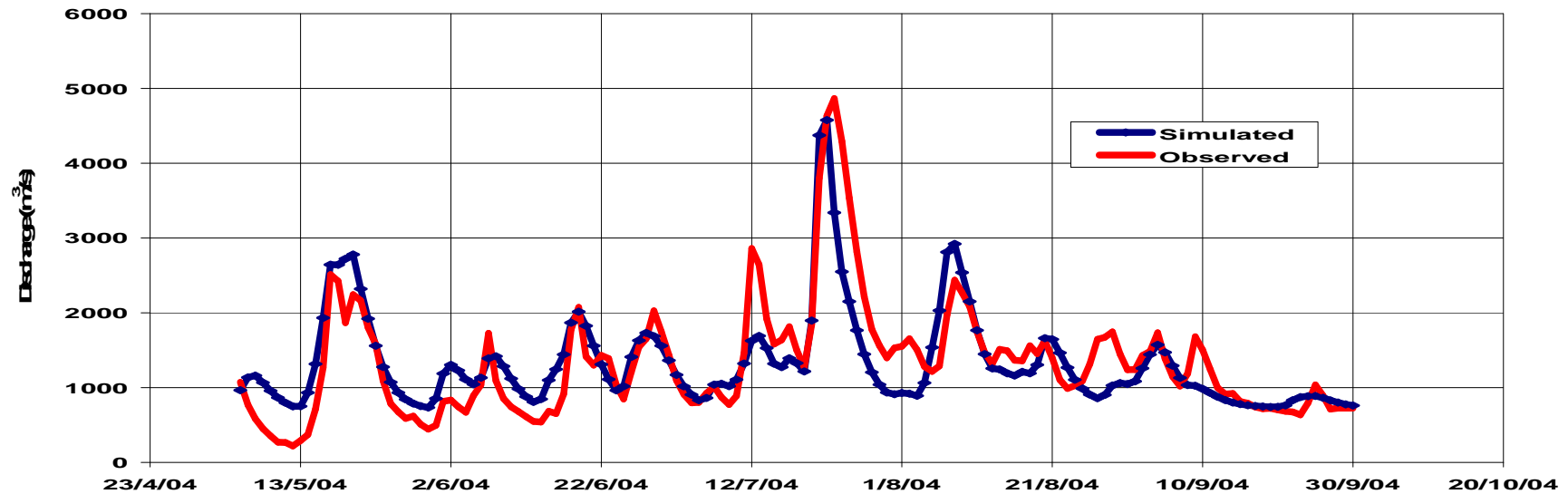


2. Application of hydrological - hydraulic models

Calibration of NAM-model: Thao at Phu Tho



Calibration of NAM-model: Lo at Vu Quang



2. Application of hydrological - hydraulic models

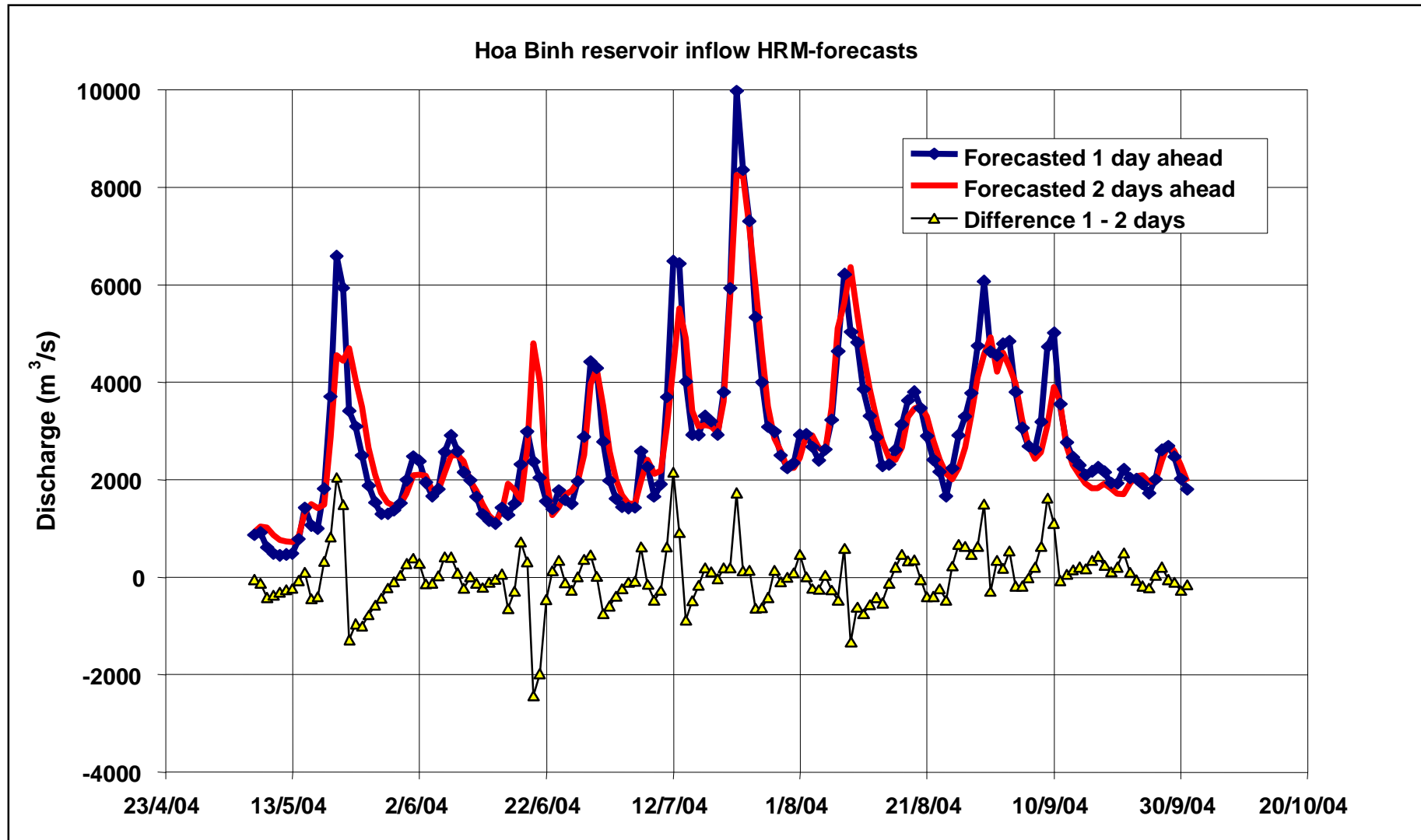
From these figures it is observed that a reasonable fit is only obtained for the Lo at Vu Quang. For the Da at Hoa Binh u/s (reservoir inflow) the model strongly overestimates the peak flows, whereas for the Thao the opposite applies

Location	Standard error	R ²	n _{NS}
Da at Hoa Binh	855 m ³ /s	0.70	0.23
Thao at Phu Tho	440 m ³ /s	0.41	0.37
Lo at Vu Quang	443 m ³ /s	0.68	0.68

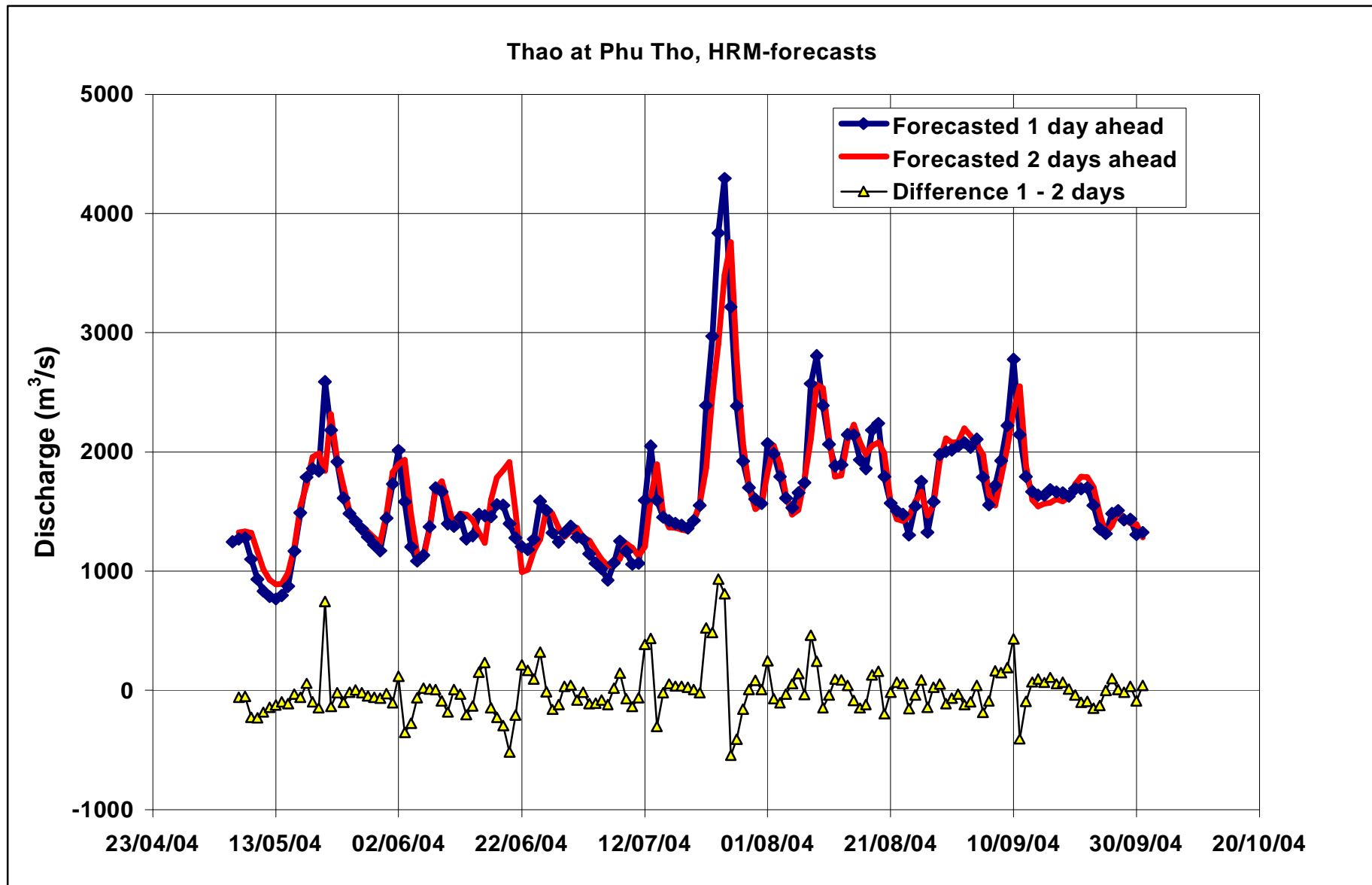
Station	No error correction				With error correction			
	See		n _{NS}		See		n _{NS}	
	HRM	JMA	HRM	JMA	HRM	JMA	HRM	JMA
Hoa Binh	1043	909	0.66	0.62	596	637	0.84	0.82
Phu Tho	440	435	0.34	0.36	231	240	0.81	0.81
Vu Quang	511	564	0.48	0.47	297	374	0.84	0.82
Average	665	636	0.49	0.48	375	417	0.83	0.82

Station	No error correction				With error correction			
	See		n _{NS}		See		n _{NS}	
	HRM	JMA	HRM	JMA	HRM	JMA	HRM	JMA
Hoa Binh	845	979	0.62	0.56	778	793	0.67	0.72
Phu Tho	434	469	0.39	0.28	333	280	0.60	0.75
Vu Quang	515	599	0.47	0.41	442	349	0.63	0.80
Average	598	682	0.49	0.42	518	474	0.63	0.76

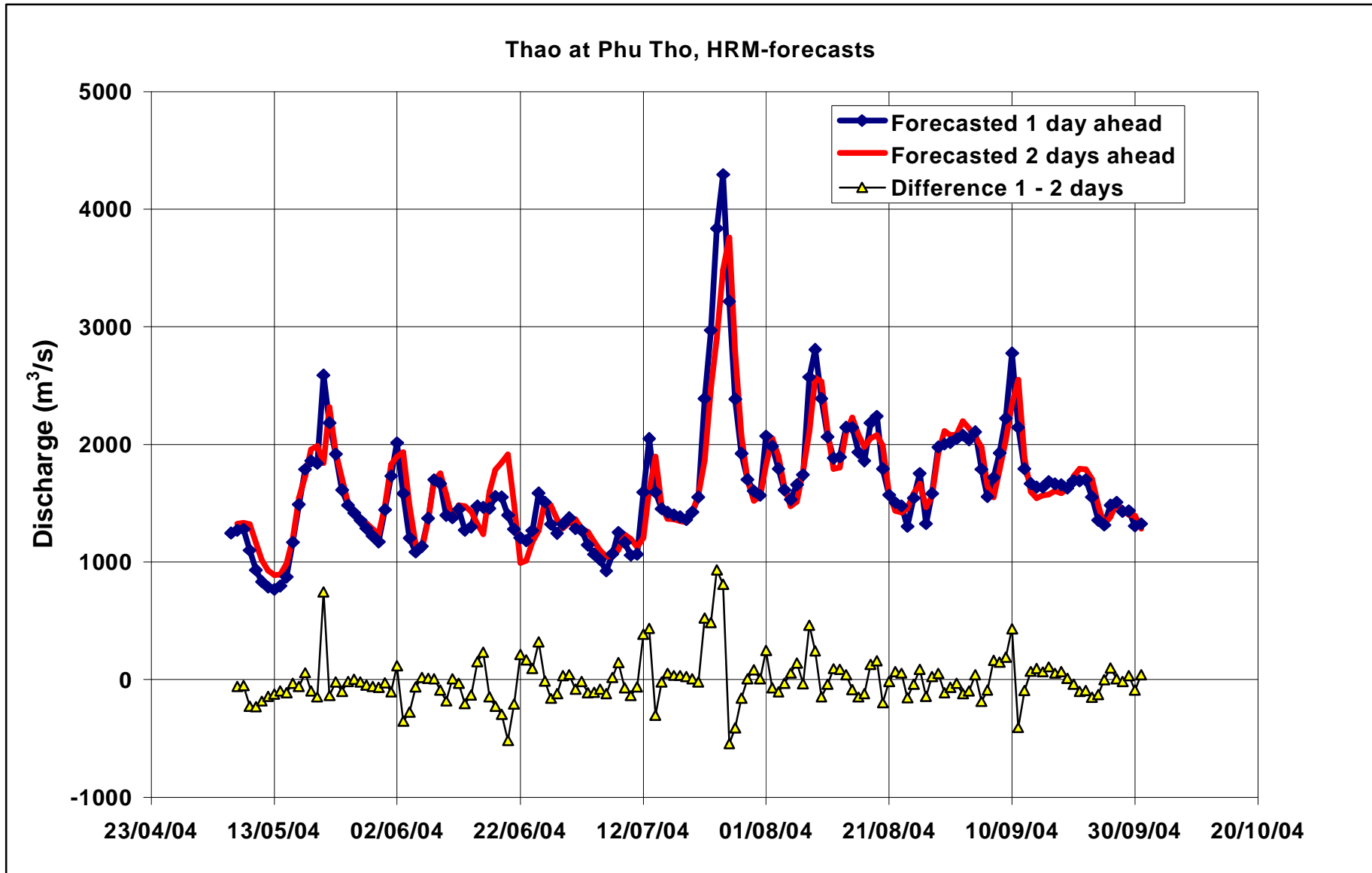
Forecasted (1 and 2 days ahead) inflow to Hoa Binh reservoir and their difference; forecasts based on HRM rainfall data and using error corrections to simulated flows



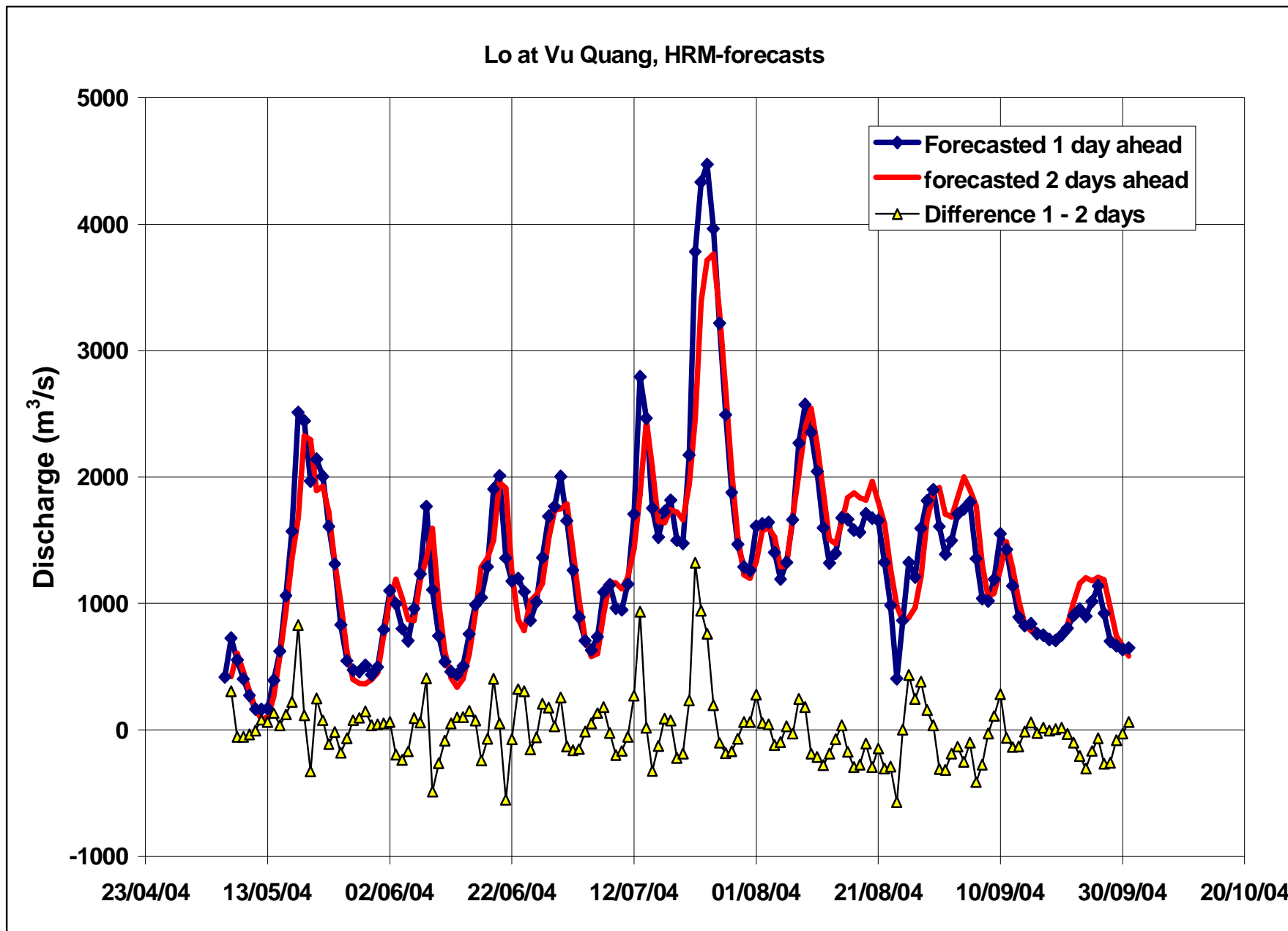
Forecasted (1 and 2 days ahead) flows in Thao river at Phu Tho and their difference;
forecasts based on HRM rainfall data and using error corrections to simulated flows



Forecasted (1 and 2 days ahead) flows in Thao river at Phu Tho and their difference; forecasts based on HRM rainfall data and using error corrections to simulated flows



Forecasted (1 and 2 days ahead) flows in Lo river at Vu Quang and their difference; forecasts based on HRM rainfall data and using error corrections to simulated flows



3. Data assimilation

- Data assimilation and updating procedures may be categorised in four different approaches: Updating of input variables; Updating of model state variables (the Kalman filter that is well proven for linear systems and the Extended Kalman filter for non-linear systems); Updating of model parameters; Updating of model outputs or error correction.
- In this study use of error correction: Linear regression equations, based on the observed and forecasted output during the entire forecasting period, have been established for each lead time. In addition an error term is added to the simulation result, by making use of the fact that at least for the shorter lead times the forecast errors are serially correlated. Hence, the following procedure is applied:

$$Q_{t+n\Delta t} = a + b \cdot Q_{NAM,t+\Delta t} (P_{t+n\Delta t}, P_{t+(n-1)\Delta t}, P_{t+(n-2)\Delta t}, \dots) + c(Q_{obs,t} - Q_{forecast,t})$$

where: $n\Delta t$ = forecast lead time

Q_{NAM} = discharge forecasted by NAM model

P = precipitation

a, b, c = regression parameters

- Forecasting error may be caused by many reasons like scarcity of rain gauge points; their unrepresentativeness; areal mean rainfall not yet taken into account of orographic effects in view of the topography; not optimum calibration of hydrological and hydraulic models.

Conclusions and recommendations

1. It is available using Mike11 software with weather forecasts (numerical and satellite) for lead-time extension and accuracy improvement of hydrological forecasting.
2. Needed adjust the areal rainfall prior to model calibration. Due attention should be given to the representativeness of the point rainfall locations in view of orographic effects.
3. Develop properly calibrated rainfall-runoff and river routing models for the sub-basins. The tools to be selected should allow for multiple data assimilation options to improve the forecasts.
4. Analyze in a similar manner, extended also to investigations for the sub-basins separately, to increase accuracy and extent lead-time of forecasts to 5 days.
5. Analyze the characteristics of the forecast error as a function of lead time, making a base for error calibration and forecasting evaluation.
6. Utilize IFAS (Integrated Flood Analysis System) using rainfall data from earth observation satellites (EOS) and other remote sensing data and implementing runoff calculation and flood prediction without excessive dependence on ground observation hydrological data.

A photograph of a building with a tall tower topped with a white sphere, partially obscured by trees, with the text "Thank you for your kind attention!" overlaid. The scene is set against a clear blue sky with some light clouds. The building is a multi-story structure with a prominent arched entrance. The tower is a lattice structure with a large white sphere at the top. The trees in the foreground are lush and green, partially obscuring the building and tower. The text is in a large, white, sans-serif font, centered on the right side of the image.

**Thank
you for your
kind attention!**