Hydrological Impact of Dual-Polarization Doppler Radar Data in mountainous areas: A case study of Typhoon Vipha (2020) in Upper NAN Basin

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ABSTRACT

Weather Radar observation is a remote sensing measurement. It uses electromagnetic wave reflection. It is expected to reflect rainfall droplets and interpret rainfall values. Not only rainfall droplet reflection but other objects also reflected by the radar beam. They are including living things such as birds and bats, and non-living things like mountains, airplanes, and buildings. Thus, it is necessary to filter these objects out. This study aims to improve rainfall measurement by filtering with Velocity and Cross correction ratio. The result shows that the radar-based has more accuracy. When utilizing radar-based rainfall as an input for hydrological model, the statistical score are RMSE = 32.38, MAE = 11.18 and PE = 26.1. The result is not different from directed-measurement rainfall. Due to radar-based rainfall missing in some areas, causing the hydrological model error. If the improved radar-based rainfall equation is used, the hydrological model will show an accurate result.

1. INTRODUCTION

A weather radar is an important tool for meteorological services and atmospheric study agencies. Recently, dual-polarization is developed which can detect more accurate raindrops. A High-resolution forecast is required by the public and can be done with a numerical weather forecast for many purposes such as an input dataset of the multi-dimension flood simulation. Spatial rainfall with high resolution is the prominent of this tool not only temporal but also area. To calculate Arial rainfall from radar, a mathematic equation is applied with data from rain gauge (Villarini and Krajewski, 2010). Radar-based rainfall sill has some uncertainly - for example, the weakness of signal by blockage and reflection of the object. Dual polarization can reduce this kind of uncertainly of radar-based rainfall (Dufton and Collier, 2015).

One of many reasons that rainfall from radar has an uncertainty is the reflection of objects that do not raindrop, sometime it reflects surface matters called ground clutter. Living things or biological scatterers also blocks radar beam such a bird and bug, in some cases, non-living thing flying such as an airplane and sea wave clutter. Static technic can erase noise from a none-movement object, but dynamics filter technic from one axis and two axes can filter ground clutter and achievement in a variety of noise clutter (Dufton and Collier, 2015)

The Upper Nan River basin is selected as the study area, located in the north of Thailand, This area is out of reach of a rain gauge, nearest rain names Thun Chang, it is river source area of Nan river basin. Because of flood problems in this area in the wet season, and lack of water

in the dry season, it depends on natural river flow without structure management although Nan river basin has Sirikit dam in lower of basin only solve a problem in the lower basin. Flood in the upper area has an effect to a landslide which affect to many people living in this area. People in a lower area such as the Chao Phraya basin also have an effect of this phenomenon because of the geography of the confluence of the river basin. Alternate land use is also the reason for floods in the study area.

In this study, radar-based rainfall is used as an input of the hydrological model name Tank model to address the efficiency of the rainfall dataset from radar. The outlet of Tung Chang water station is selected as a study point, the first order station in the river basin operated by TMD. Rainfall is the main factor that triggers the river flow in basin difference from other point stations that receive water from the upper area.

2. METHODOLOGY

2.1 Study area

Upper Nan river basin is sub-basin of Nan river basin has 2,221.82 km^2 as 6.36% of the Basin covers seven districts as following Chaleam Prakeat, Chiang Klang, Tha Wang Pha, Thung Chang, Boa Klea, Pua, and Song Keaw in Nan province. The topography of the Basin is a source of water in the watershed and has a mountainous area and high ground 1400 – 1900 meter mean sea level with five rivers. Population Depends on Agriculture for occupation (DWR, 2018)

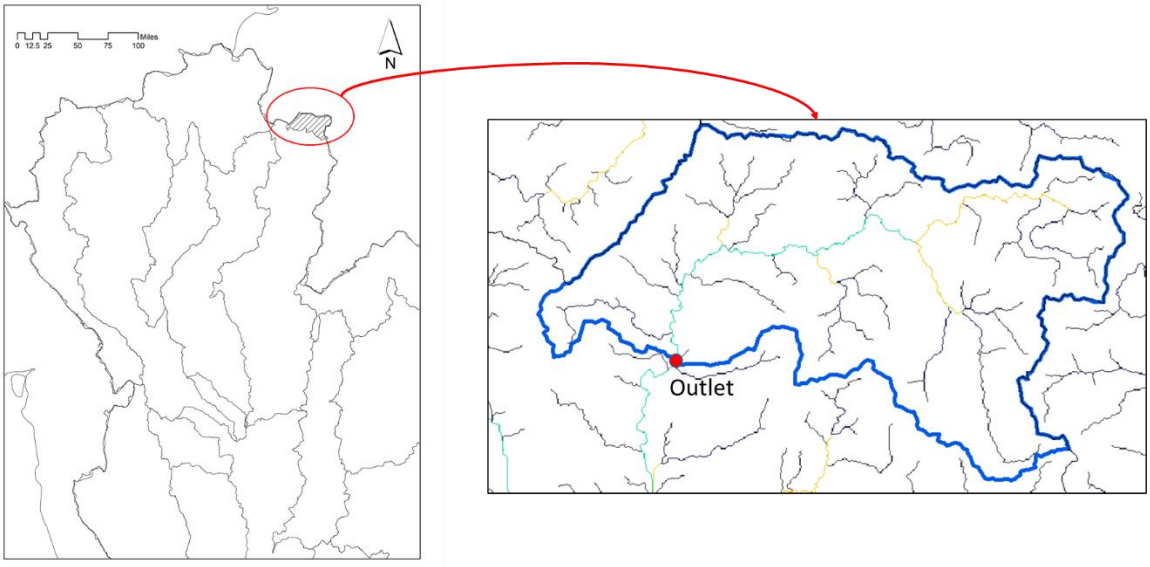


Figure 1. Study area

This study aims to find the performance of radar-based rainfall as input of Tank model for Tung Chang station when heavy rainfall during tropical cyclone event occurring in 2019

2.2 Data collection

1. Radar-based rainfall from Tha Wang Pha radar station in Nan province from 2-5 August 2010 which affect by tropical storm Vipa collecting in UF file format interval 15 minutes in temporal by TMD database.

2 Point rainfall by TMD serviced by Climate information service, CIS from 1 January 2018 to 21 April 2020 for adjusting the Tank model.

3 Water level and volume from RID and TMD from 1 January 2018 to 21 April 2020

2.2 Data collection

The main purpose of using Radar-based rainfall is to extend the rainfall network in a remote area which rain gauges not covering on the far side of the basin. The remote area is a water source with the natural flow and non-controlling system with dangerous river shape, narrow and steep shape, water level changes rapidly causing to harm people in a riparian area. The flow chart of the study shows in the figure below.

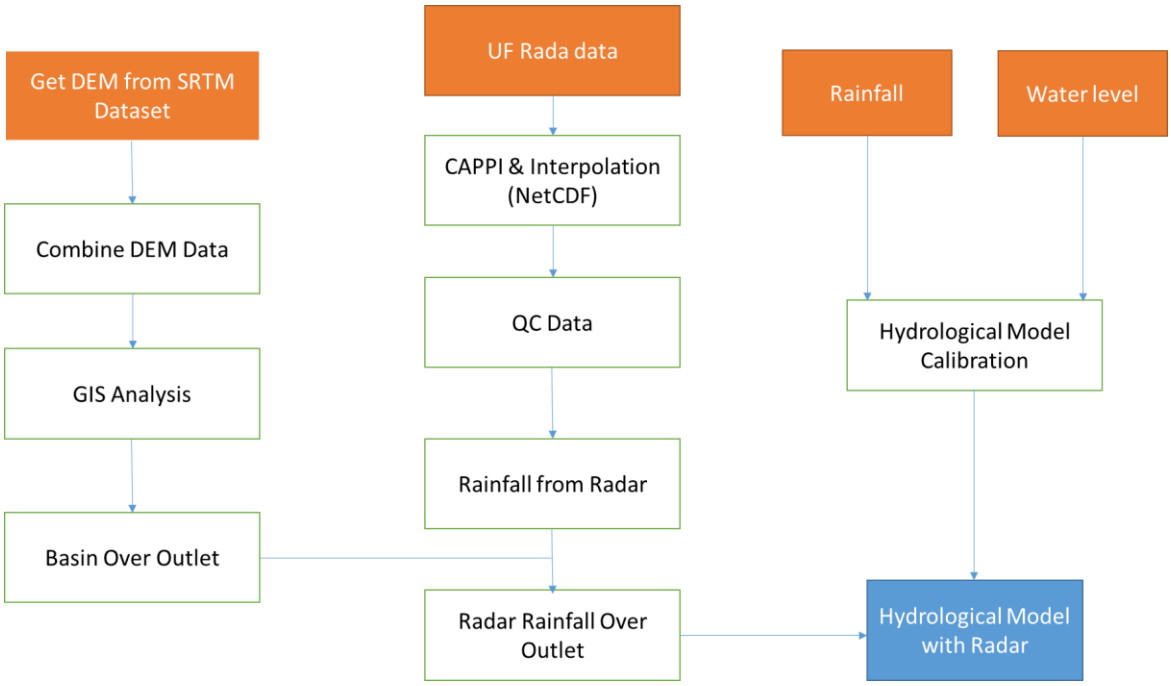
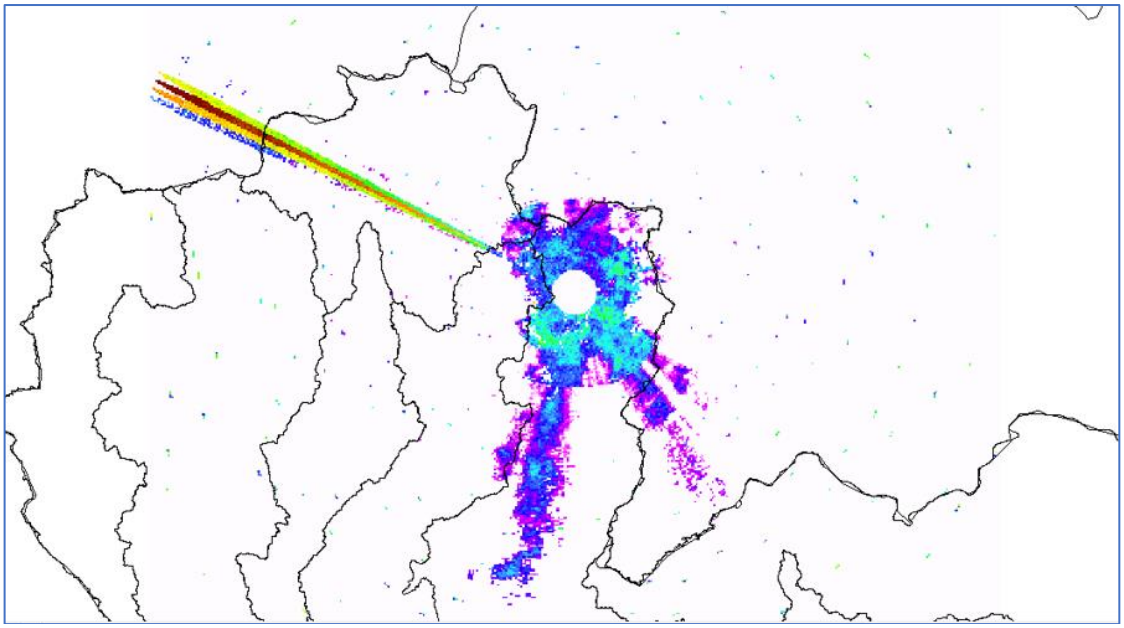


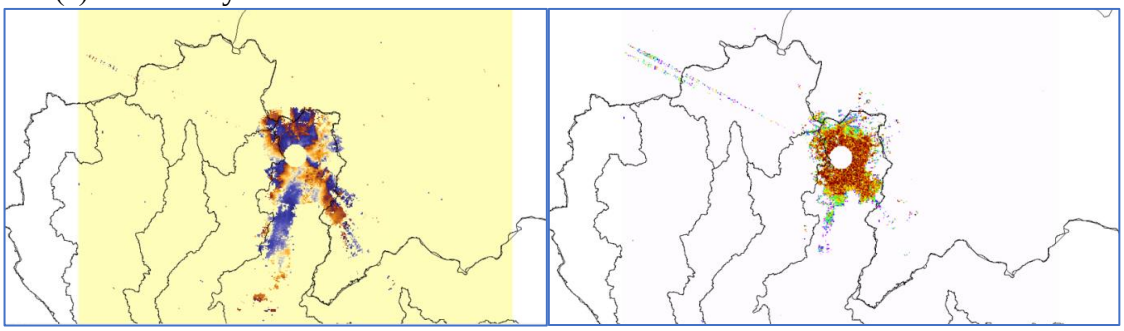
Figure 2 workflow of the study

Script for analysis data is created in NetCDF File and TIFF File that suitable GIS tasks such as ArcGIS and QGIS. The parameter is the magnetic reflection of raindrops, velocity, and Cross-correlation ratio compress as CAPPI at 1km vertical high as shown in the figure 3.

How to devise clutter from raindrop, velocity, and cross-correlation ratio are utilized. If the object stays still, it is no movement and velocity equal to zero. Likewise, cross-correlation ratio is the relation of refection between two axes, when cross-correlation ratio near 1, it's rain.



(a) reflectivity of radar



(b) Velocity data (c) Cross correlation ratio

Figure 3. Radar data

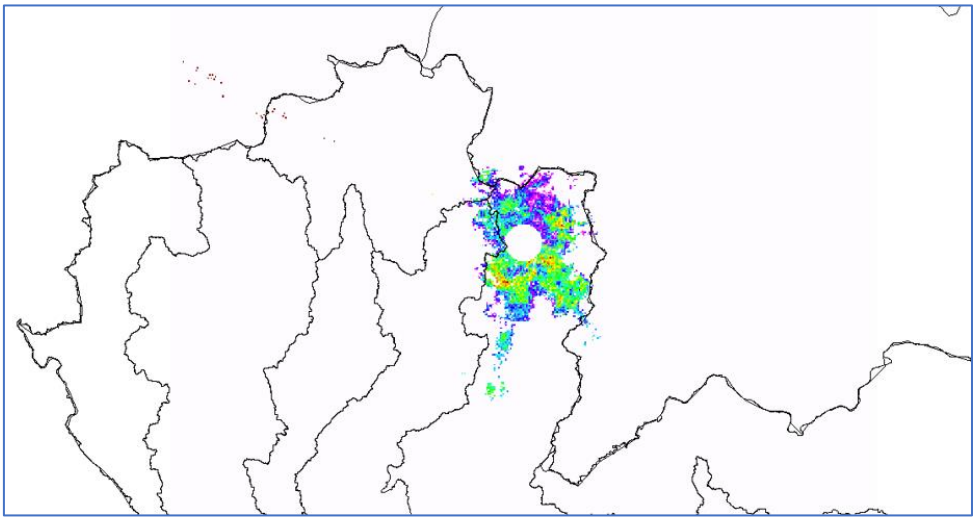


Figure 4. filtered radar data

The transformation from reflectivity to rain rate, Z-R relation equation is adopted with $Z = 250R^{1.2}$. this equation is suitable for tropical weather zone (Einfalt et al.,2004) when R stands for rain rate(mm/h) and Z is radar reflectivity (mm^6/m^3).

To compute drainage area in study basin and fine water volume that fill in the Tung Chang river station, GIS is applied to analyze rainfall in watershed.

Tank model is written in computer program names python and uses rain gauge network data set to calibrate and verify Tank

Tank Model is one of a user-friendly hydrological model in term of setting model and calibrating lumped properties. Tank is arranged vertical and represents surface interflow and base flow depend on the modeler decision. (Sugawara et al., 1995)

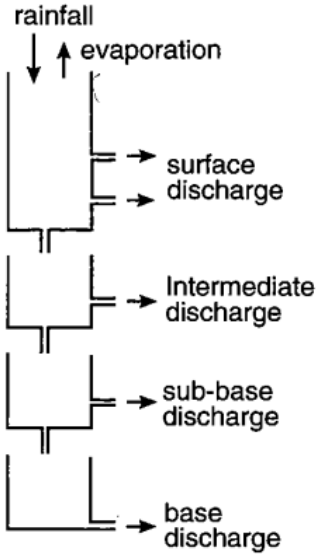


Figure 5 Tank model

3. RESULT AND DISCUSSION

Radar based-rainfall and rain gauge network dataset from 2-5 August 2010 which triggers heavy rainfall widespread in northern Thailand by tropical storm Vipa is used as input of Tank model separated in two cases: 1. Tank model with radar rainfall 2. Tank model with a rain gauge. The result shows that discharge that generating from remotely sensed data is slightly lower than rain gauge input data. This can adjust the radar equation to improve the accuracy of rainfall input. However, Statistical verification points out less error from radar base model than rain gauge base including mean absolute error (MAE), root mean square error (RMSE) and percentage error (PE).

The result from using Velocity and Cross-correlation ratio to filter noise from Radar rainfall product found that filtering is good enough when erasing mountain in water source area at upper of study basin as shown in figure 7(a). The point that showing in the picture means filtering successfully and figure 7(b) shows flirted rainfall map and the missing area can be replaced by composting with a nearby radar station and satellite rainfall too.

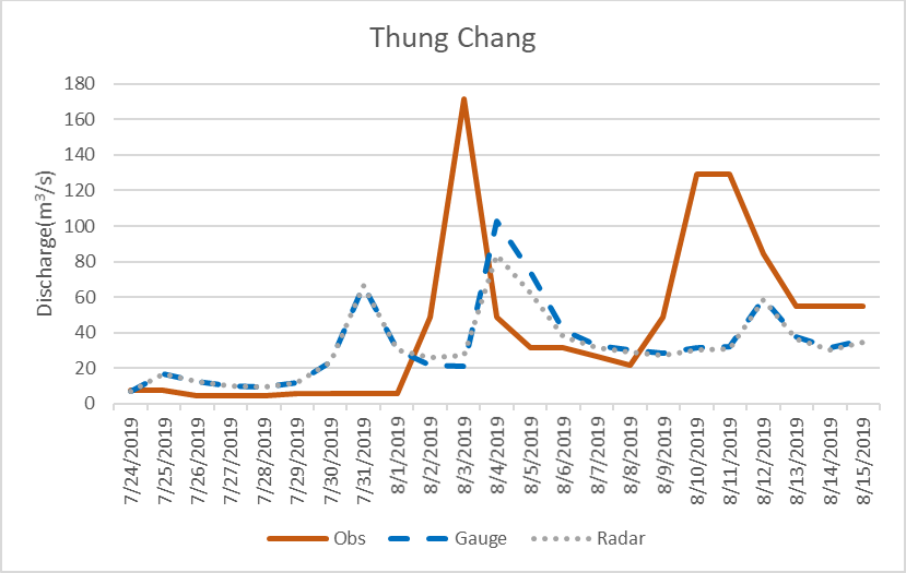
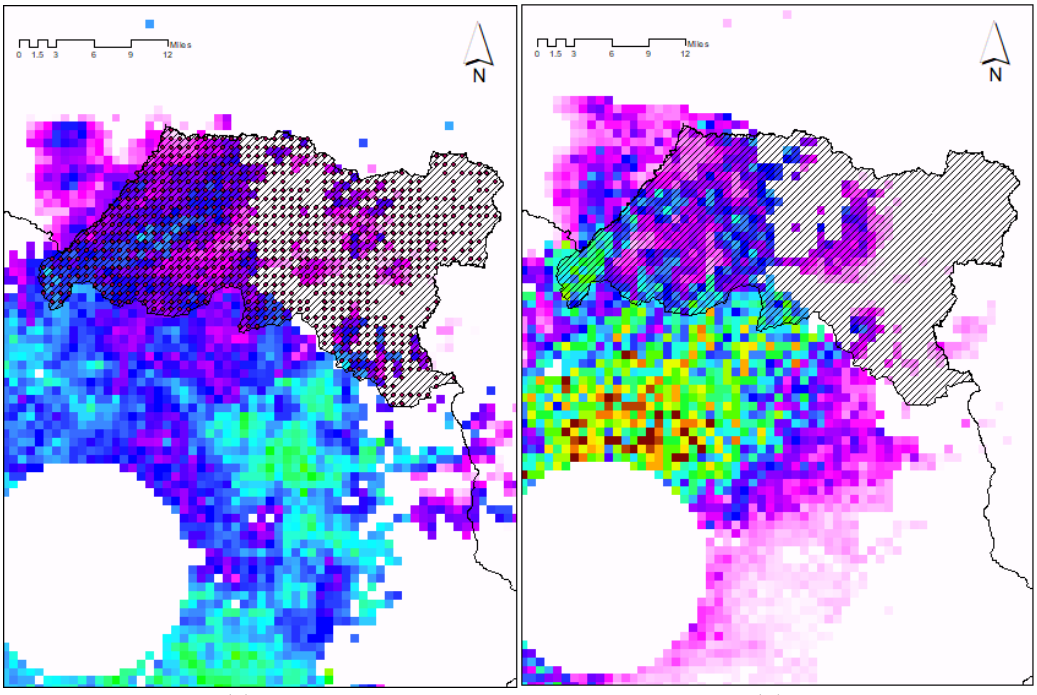


Figure 6 Discharge from observation, rain gauge input, and radar input

Table 1. Error of Tank model comparing radar base model and gauge base model

Input data	RMSE	MAE	PE
Rain gauge	35.25	12.95	30.22
Radar	32.38	11.18	26.11



(a) (b)

Figure 7. Data filtering

(a) Filtering with Velocity and Cross correlation ratio
(b) Filtered rain fall map

The equation with $Z = 250R^{1.2}$ is suitable for the tropical area where air mass convection and condense to rainfall, but Marshall and Parmer with $Z = 200R^{1.6}$ applied in this study, rainfall volume is diminished and needs calibration for more accuracy. On the other hand, Mean-field bias (MFB), Range dependent adjustment (RDA), Special bias adjustment (SBA), or Static local bias adjustment and range dependent adjustment (SRD) may be tested in the next experiment with ground truth (Mahavik, 2017)

This study is not a separate Tank model in a wet and dry period when calibration model, error take place come from this reason. This is because water levels change rapidly in the transition phase of wet and. If separate wet-dry season, the result will be improved.

The rainfall data set that uses as an input of the model is an aerial rainfall with the whole basin, some periods or some stations are missing and need to interpolate the data set causing a small amount of rain volume in a basin to fulfill with bias correction.

Moreover, filtering radar rainfall makes some error with missing data and need to fill the gap of missing data with another radar station. Lastly, some data set has an error with false rainfall event, no rain with rain data, it is a main source of error in the model, Radar can be used as truth checked of this event.

4. REFERENCES

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