Technical Conference (TECO) Embracing New Technologies and Knowledge to Meet the Challenges in the New Era of Tropical Cyclones Forecasting, Ha Noi, 26-27 February 2018.

Using Satellite Observation for Monitoring and Warning of Temperature Clouds Relationship Precipitation in Thailand

Kamol P.N. Sakolnakhon[a*], Peeranut Longsomboon[a] and Sarintip Tantanee[b]

[a]*Radar and Satellite Data Analysis Division, Weather Forecast Bureau, Department, Thai Meteorological Department,*

[b]*Fucculty Engineering, Naresuan University, Phitsanulok, 99 Moo 9 Tambon Tha Pho, Muang Phitsanulok, 65000.*

promasakha123@hotmail.com

1. Introduction

Currently, scientists have estimated rainfall with the remote by using weather radar and meteorological satellite instead of installed observation stations over forest areas and steep mountains. Scientists trying to estimate the spatial rainfall from meteorological satellites are as follows.

Rasamee, Swanwerakamtorn (2000) had studied the qualitative precipitation estimation (QPE) from 42 rain gauges observation by the geographic information system (GIS): ***Thiessen Polygons, Moving Average, Moving surface, Trend surface and Kriging method.*** The results showed that the Moving Average with Inverse Distance Weight (IDW) got results of the spatial rainfall in the area better than other methods.

1. Introduction (Cont.)

Kamol P.N. Sakolnakhon and S. Tantanee (2007) had studied satellite rainfall estimation in Thailand using FY-2C Infrared data which cloud temperatures (IR). The relationship between IR data and rain rate collected from Thailand Meteorological Department (TMD) has been analyzed. The result shows, for cold cloud (IR<253K), polynomial relationship between IR1 and rain rate with acceptable R^2 at 0.79.

1. Introduction (Cont.)

Kamol P.N Sakolnakhon. and S. Tantanee. (2013) studied the verification statistics used in evaluating of the estimate rainfall from satellite over Thailand during 2000-2010 periods. The satellite data from GSMaP_MVK (TRMM/TMI, Aqua/AMSR-E, ADEOS-II/AMSR, DMSP/SSMI) have resolution grid about 0.1degrees from the Japan Aerospace Exploration Agency (JAXA), rainfall observed from stations of Thailand Meteorological Department (TMD). The assessment of the accuracy GSMaP_MVK has two experiments, the first experiment studied the estimated rainfall over all seasons, the summer (mid-February to mid-May), rainy (mid-May to mid-October) and winter (mid-October to mid-February). The second examined the estimated rainfall from tropical cyclones.

1. Introduction (Cont.)

Results showed that GSMaP_MVK is under estimated rainfall form observation, perfect in rainy season, and quite weak in summer season.

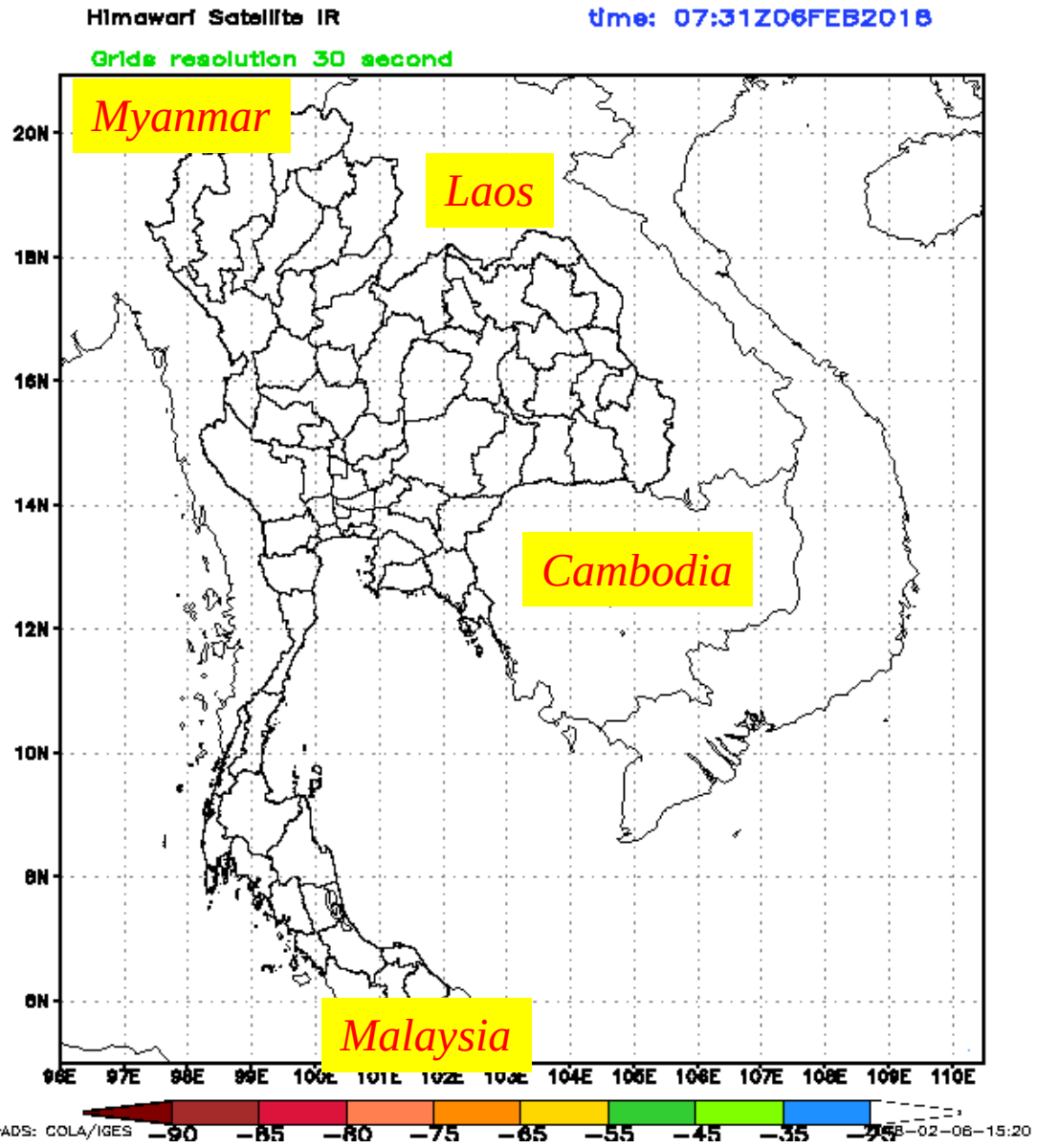
Watcharee Veerakachen, Mongkol Raksapatcharawong and Shinta Seto (2014) had studied the performance evaluation of Global satellite mapping of precipitation (GSMaP) products over the Chao Phraya river basin in Thailand. The experiment using GSMaP data of GSMaP_MVK is a non-real time and GSMaP_NRT is a near real time, results of GSMaP_NRT is quite good but not sufficient for real time.

Kamol P.N Sakolnakhon and S. Tantanee. (2014) had studied the qualitative precipitation estimation (QPE) cover Thailand with ***an hour data during May to November 2014 from the geo-satellite of FY-2E and used technique of the Inverse Distance Weight (IDW) method.*** Results showed that the temperature of cloud (IR<253K) which R-T relationship in a polynomial of the relation temperature (IR1) and rain rate is acceptable; R^2 is 0.6673, CC is 0.8269, POD is 0.7801 and TS is 0.6603, are perfect enough accuracy of FY-2E algorithm. It indicates a good performance to the estimated rainfall in the area.

2. Study Area and Data Source

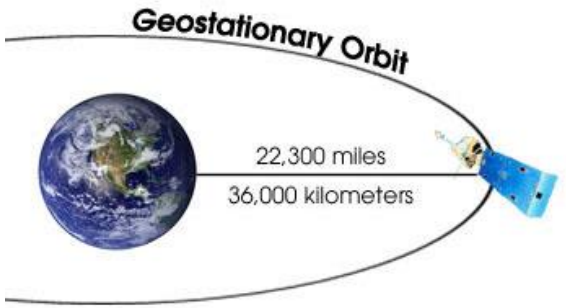
2.1 Study Area

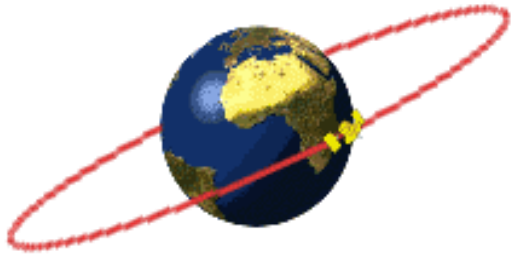
Our study area is Thailand which is situated in Southeast Asia, adjoined to *Laos and Burma (Myanmar) to the north, Cambodia and the Gulf of Thailand to the east, Burma and the Andaman Sea to the west, and Malaysia to the south. Its total area* is twice Wyoming size, about 514,000 square kilometres (198,455 square miles). The length of its coastline measures 3,219 kilometres (2,000 miles), is located ***latitude 5.62 ºN to 20.45 ºN*** and also ***longitude 97.37 ºE to 105.62 ºE.*** Its capital city, Bangkok, is the most populated city in Thailand. Located in the central region, Bangkok is the center of Thailand's economic and political activities. Major part is the north, the northeast, the central, the east and the south.



2.2 Satellite Data

In order to Japan Meteorological Agency (JMA) provides the geostationary satellite above surface about 38,600 kilometre which is located Around 140.7 degrees east covering the East Asia and Western Pacific regions, continuous Himawari satellite observation every 10 minutes by cloud service of internet, have 16 bands (IR: 10.5-12.5um, IR1: 10.5-11.5um, IR2: 11.5-12.5um, IR3(WV): 6.5-7.0um, IR4: 3.5-4.0um, Band1: 0.43100.4790um, Band2: 0.5025-0.5175um, Band3: 0.62500.6600um, Band4: 0.8495-0.8705um, Band5: 1.6011.619um, Band6: 2.253-2.268um, Band7: 3.740-3.960um, Band8: 6.061-6.425um, Band9: 6.890-7.010um, Band10: 7.258-7.433um, Band11: 8.440-8.760um, Band12: 9.5439.717um, Band13: 10.25-10.61um, Band14: 11.0811.32um, Band15: 12.15-12.45um and Band16: 13.2113.39um) which are different frequency in each band. *In the experiment used only the infrared (IR) of band13 which is 10.25-10.61um during July to September 2015, measure every 10 minute, but we selected to use every hour to average temperature clouds computed precipitation.*

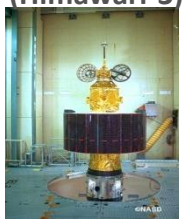




Channel	Central Wavelength [μm]	Spatial Resolution
1	0.43 – 0.48	1 km
2	0.50 – 0.52	1 km
3	0.63 – 0.66	0.5 km
4	0.85 – 0.87	1 km
5	1.60 – 1.62	2 km
6	2.25 – 2.27	2 km
7	3.74 – 3.96	2 km
8	6.06 – 6.43	2 km
9	6.89 – 7.01	2 km
10	7.26 – 7.43	2 km
11	8.44 – 8.76	2 km
12	9.54 – 9.72	2 km
13	10.3 – 10.6	2 km
14	11.1 – 11.3	2 km
15	12.2 – 12.5	2 km
16	13.2 – 13.4	2 km

History of Japanese Geostationary Meteorological Satellites "Himawari"

GMS (Geostationary Meteorological Satellite)

GMS (Himawari)	GMS-2 (Himawari-2)	GMS-3 (Himawari-3)	GMS-4 (Himawari-4)	GMS-5 (Himawari-5)
				
Jul 1977	Aug 1981	Aug 1984	Sep 1989	Mar 1995

One of the tri-Ranging Station for GMS was operated by Australian Bureau of Meteorology

(GOES-9)

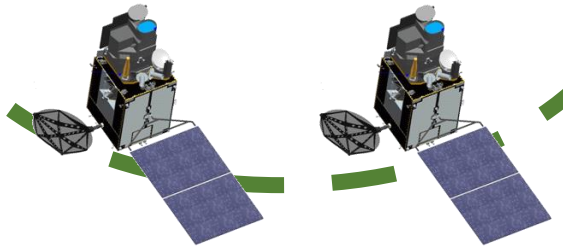
Back-up operation of GMS-5 with GOES-9 by NOAA/NESDIS May 2003 - June 2005

MTSAT (Multi-functional Transport SATellite)

MTSAT-1R (Himawari-6)	MTSAT-2 (Himawari-7)
	
Feb 2005	Feb 2006

Himawari

Himawari-8 *Himawari-9*

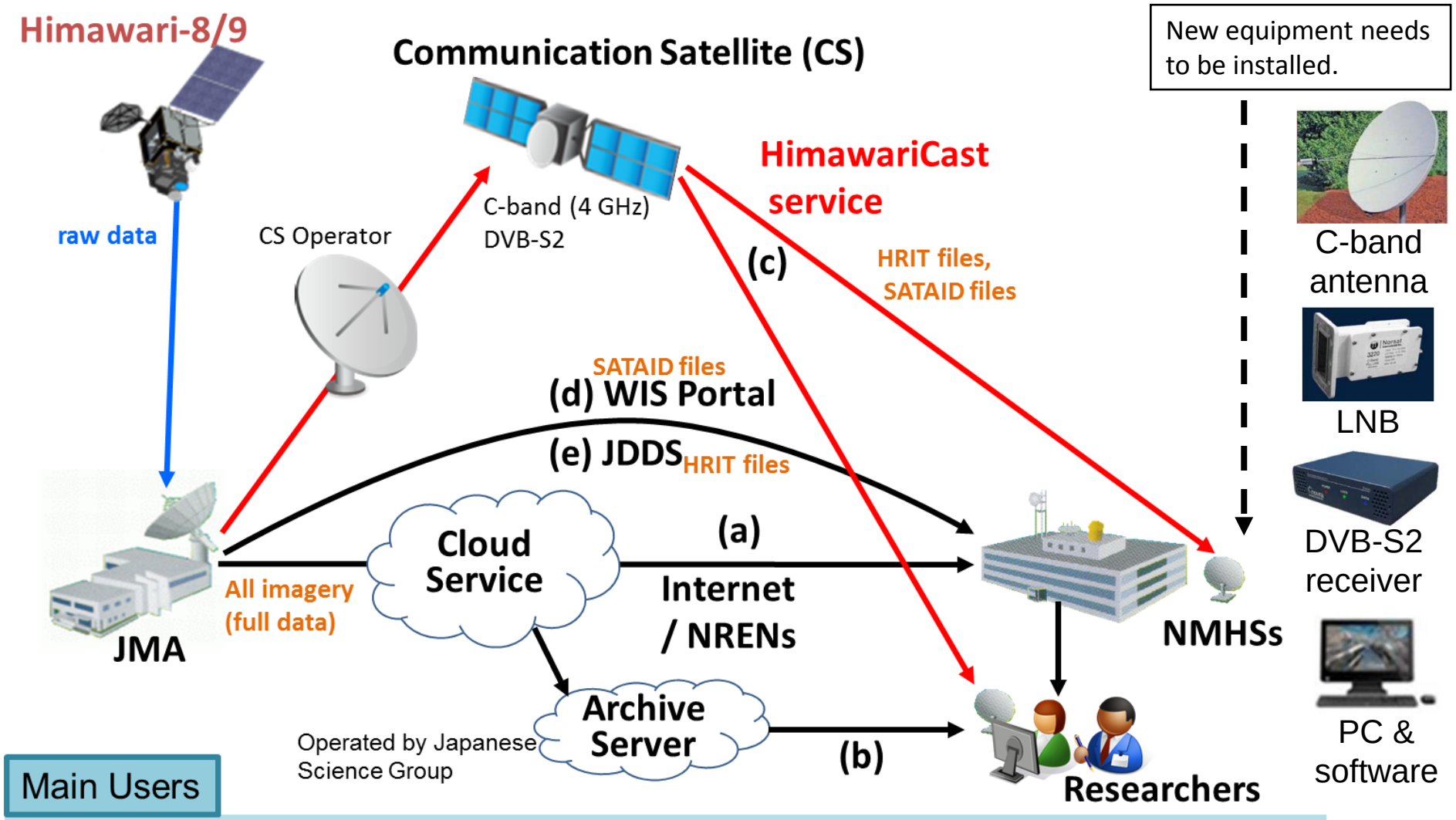


2014 2016

Satellite	Observation period
GMS	1977 – 1981
GMS-2	1981 – 1984
GMS-3	1984 – 1989
GMS-4	1989 – 1995
GMS-5	1995 – 2003
GOES-9	2003 – 2005
MTSAT-1R	2005 – 2010
MTSAT-2	2010 –
Himawari-8	Launch in 2014
Himawari-9	Launch in 2016

8

Himawari-8/9: Data Distribution/Dissemination



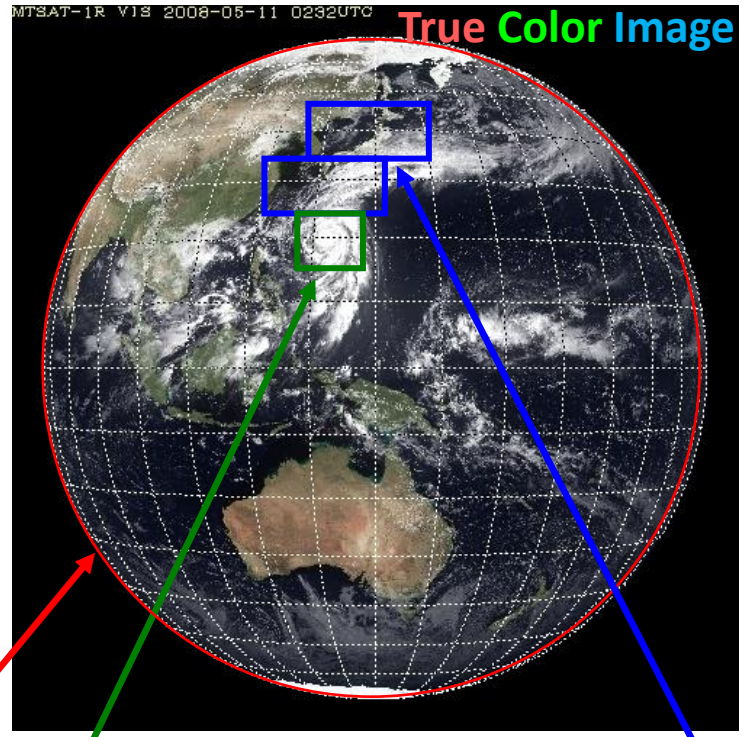
Main Users

(a) Cloud Service: NMHSs (1 agency / nation)
(b) Archive Server: Universities and Researchers
(c) HimawariCast: Every users
(d) WIS Portal and (e) JDDS: NMHSs

Himawari-8/9: Specification of Observation

Wavebands of the Advanced Himawari Imager (AHI)

Channel	Central Wavelength [μm]	Spatial Resolution	
1	0.43 – 0.48	1 km	RGB Composited True Color Image
2	0.50 – 0.52	1 km	
3	0.63 – 0.66	0.5 km	
4	0.85 – 0.87	1 km	
5	1.60 – 1.62	2 km	
6	2.25 – 2.27	2 km	
7	3.74 – 3.96	2 km	
8	6.06 – 6.43	2 km	Water Vapor
9	6.89 – 7.01	2 km	
10	7.26 – 7.43	2 km	
11	8.44 – 8.76	2 km	SO_2
12	9.54 – 9.72	2 km	O_3
13	10.3 – 10.6	2 km	Atmospheric Windows
14	11.1 – 11.3	2 km	
15	12.2 – 12.5	2 km	
16	13.2 – 13.4	2 km	CO_2



Full disk
Interval: **10 minutes** (6 times per hour)

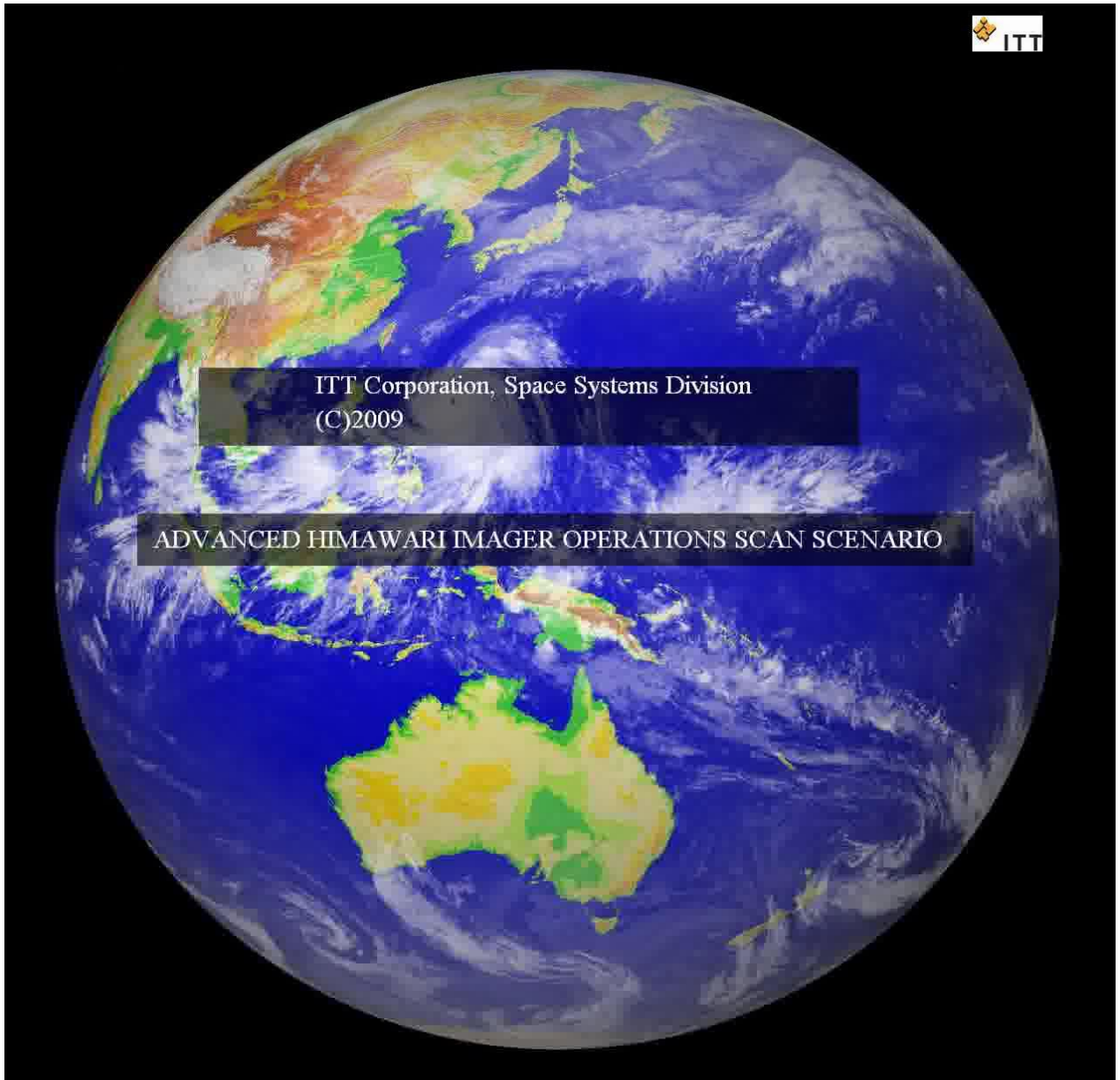
Region: Japan
Interval: **2.5 minutes** (4 times in 10 minutes)
Dimension: EW x NS: 2000 x 1000 km x 2

Region: Typhoon
Interval: **2.5 minutes** (4 times in 10 minutes)
Dimension: EW x NS: 1000 x 1000 km

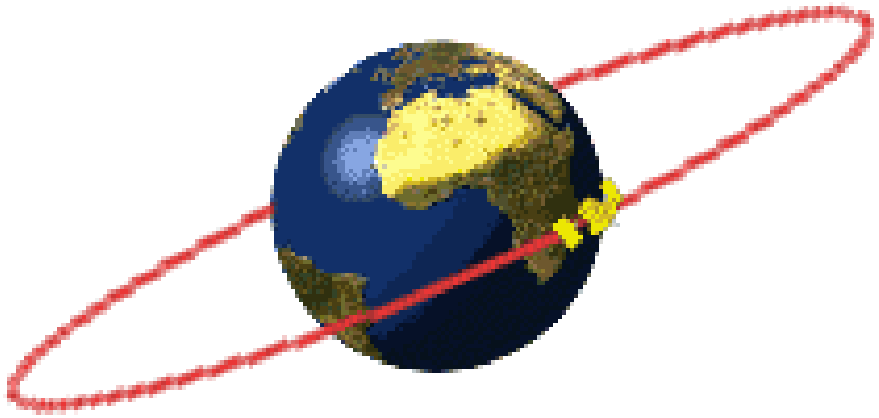
Number of Channels: 5 ⇨ 16

Interval: 30/60 min. ⇨ 10min.

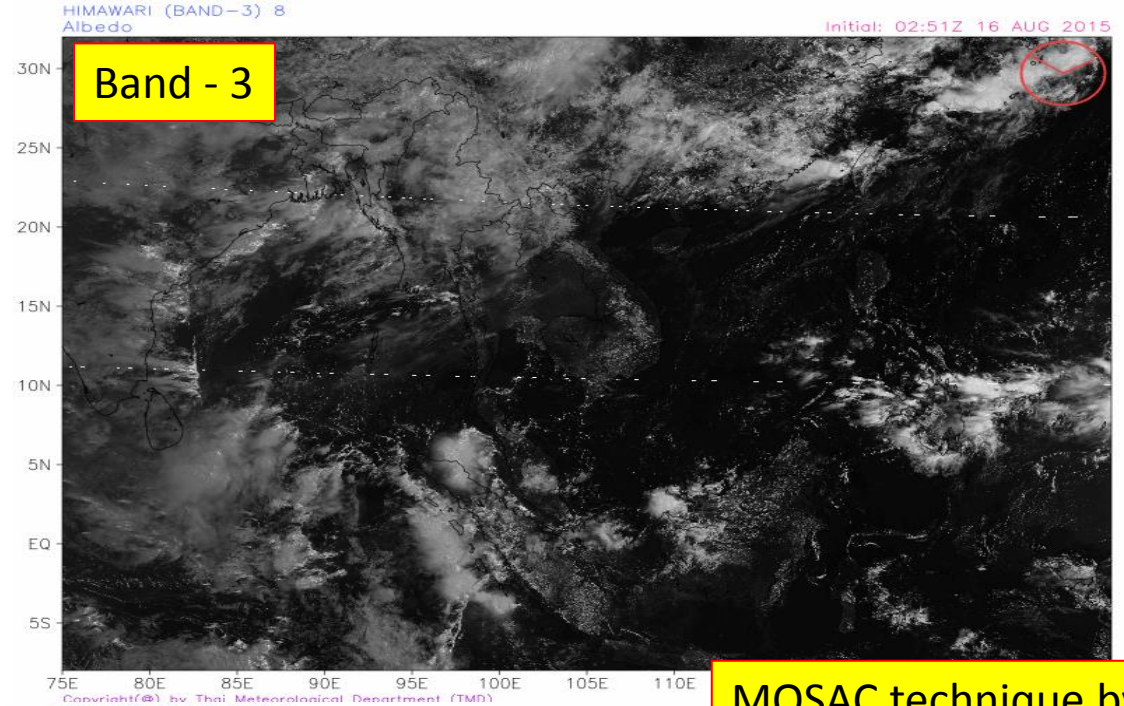
Himawari satellite measure every 10 minute

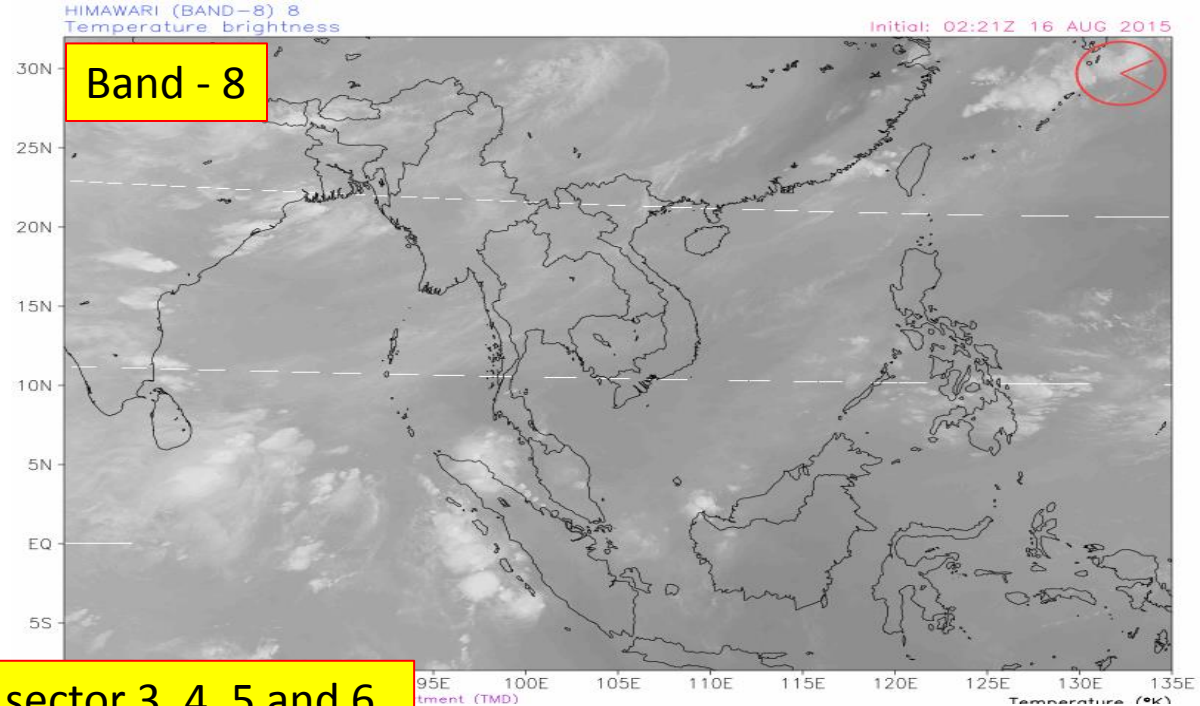


Polar orbit satellite

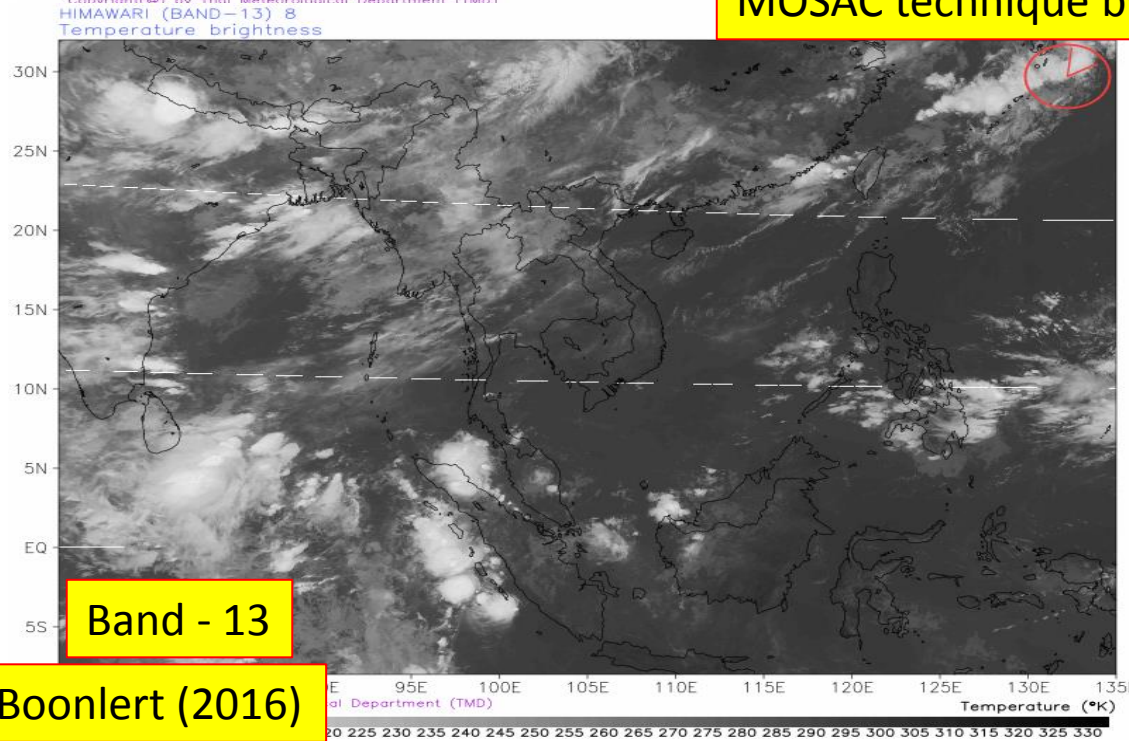


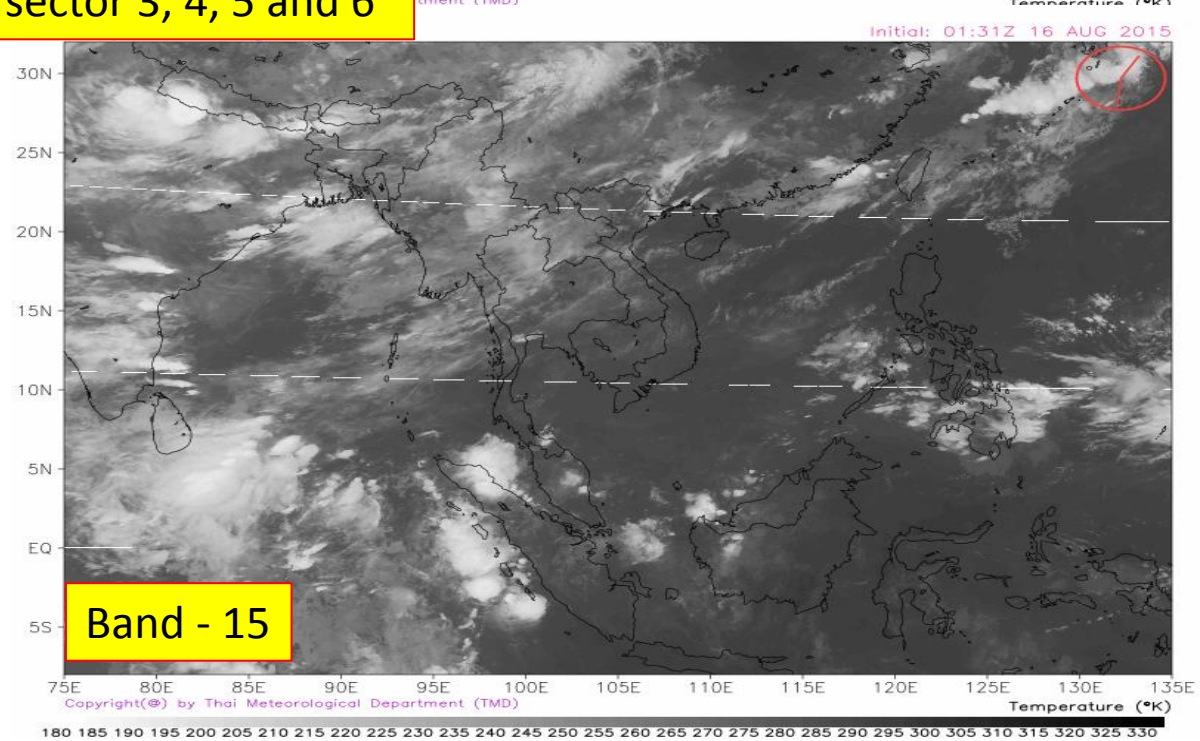
Geo-satellite





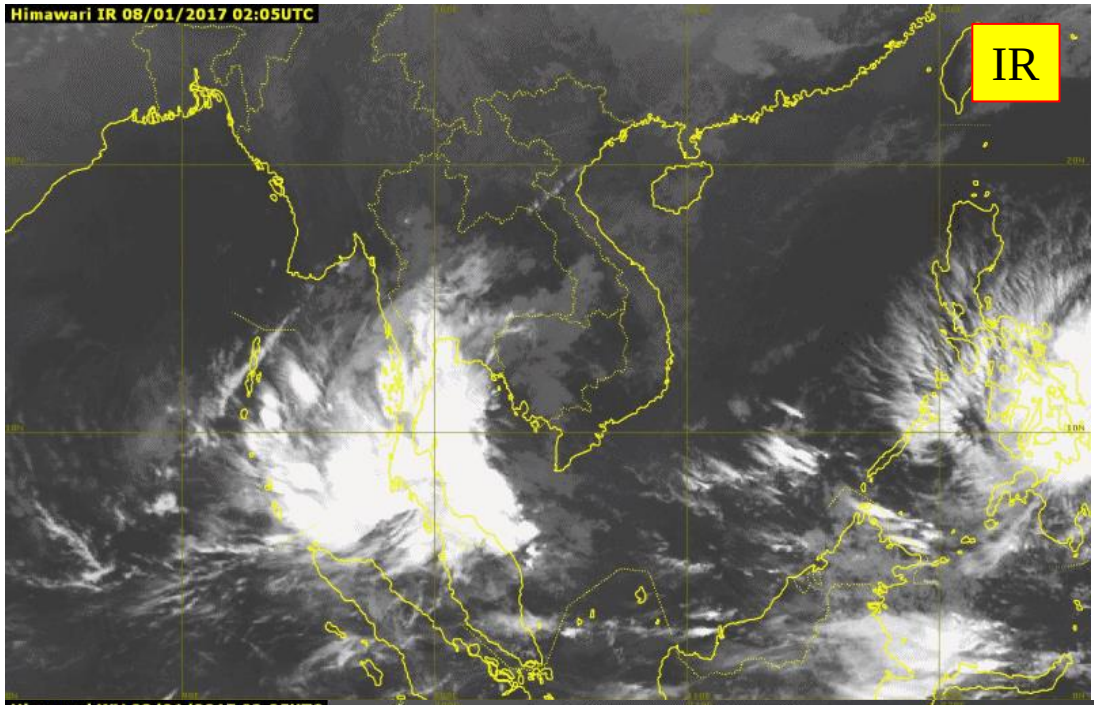
MOSAC technique by sector 3, 4, 5 and 6

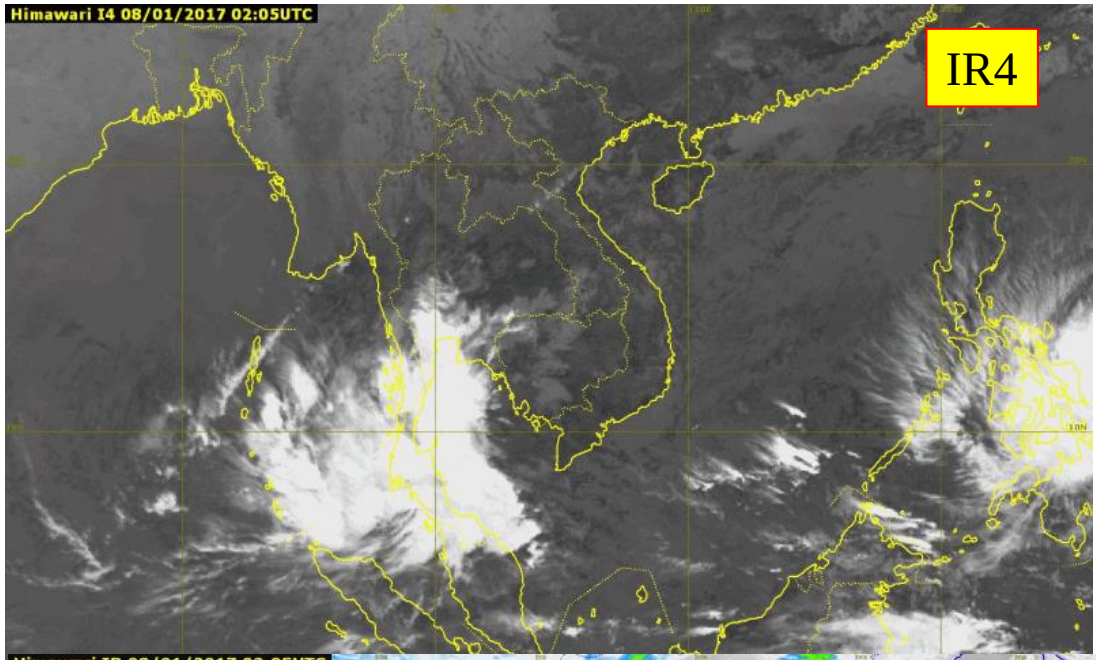


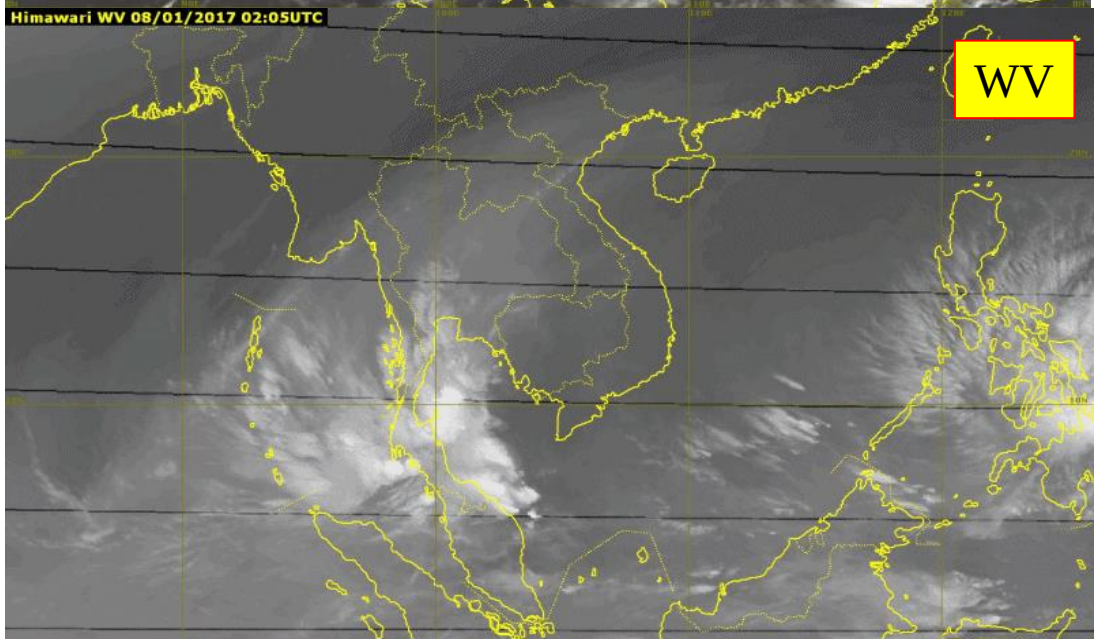


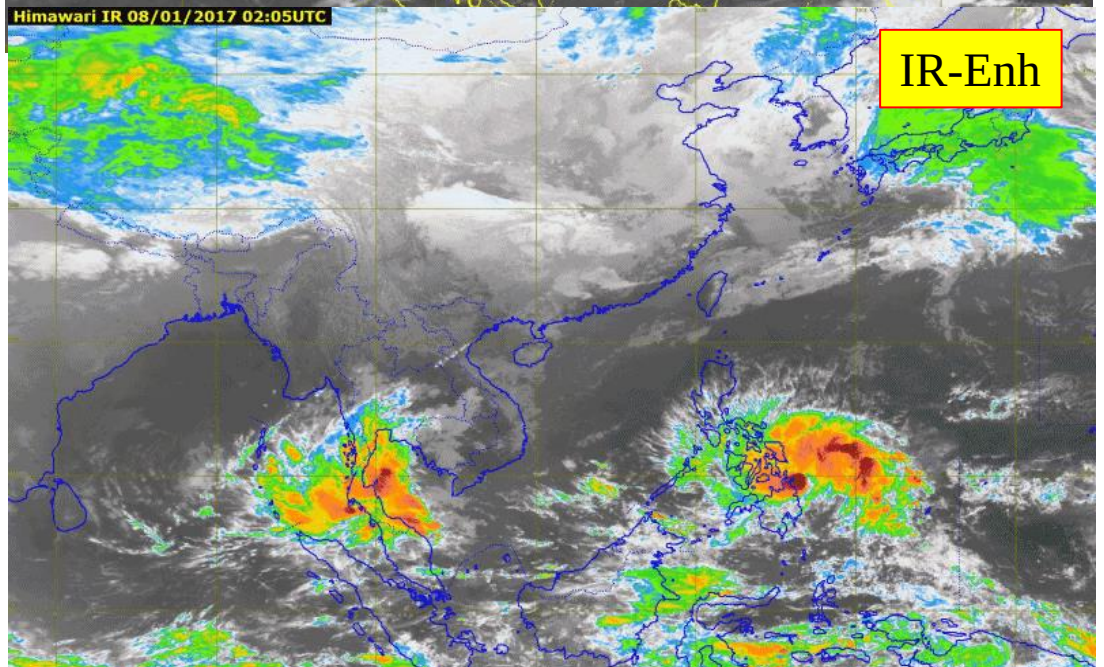
By: Boonlert (2016)

Satellite detection in each channel of sensor.

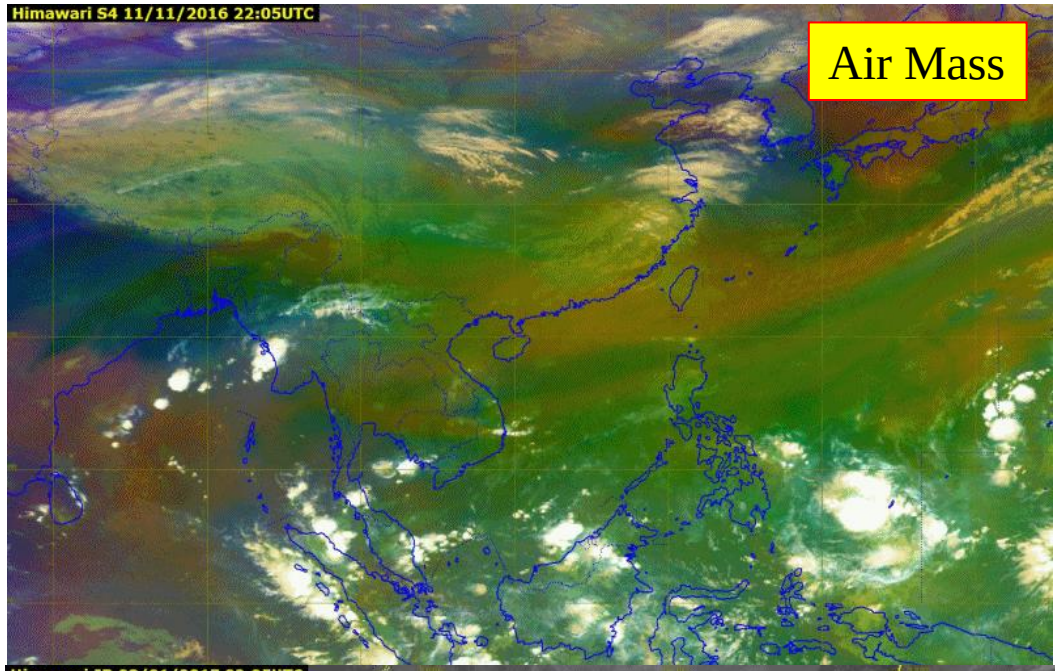


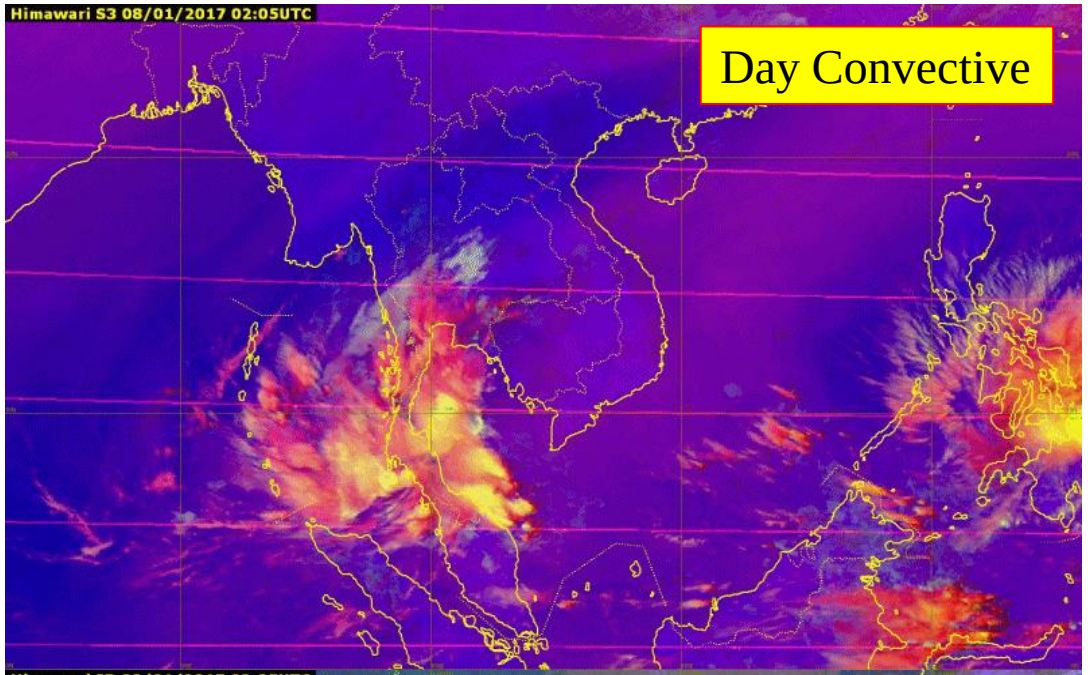


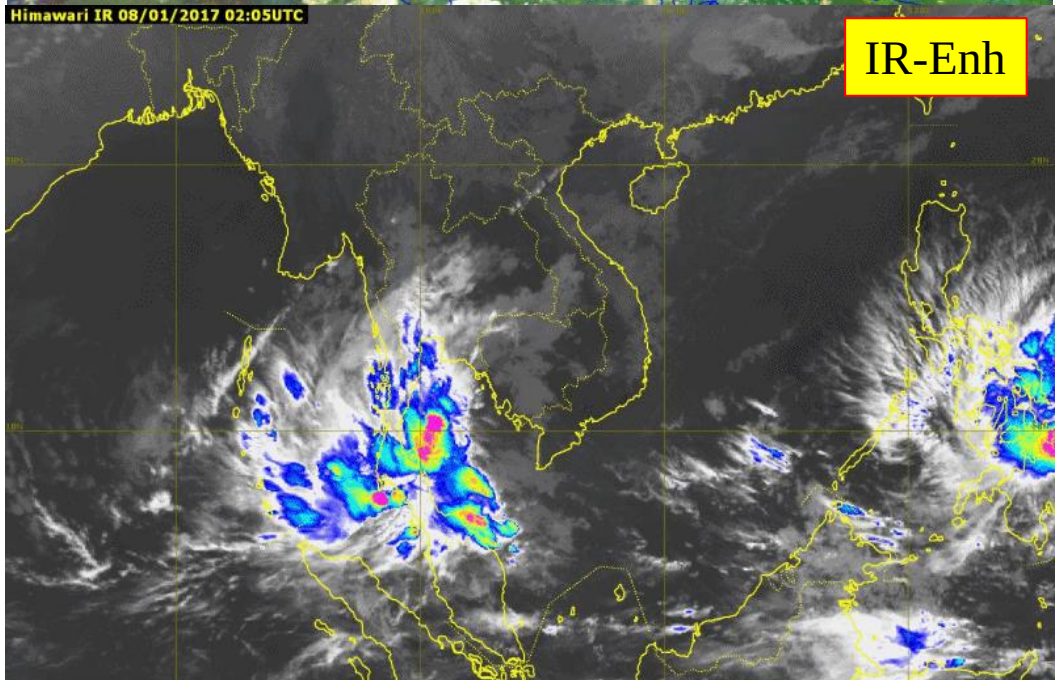


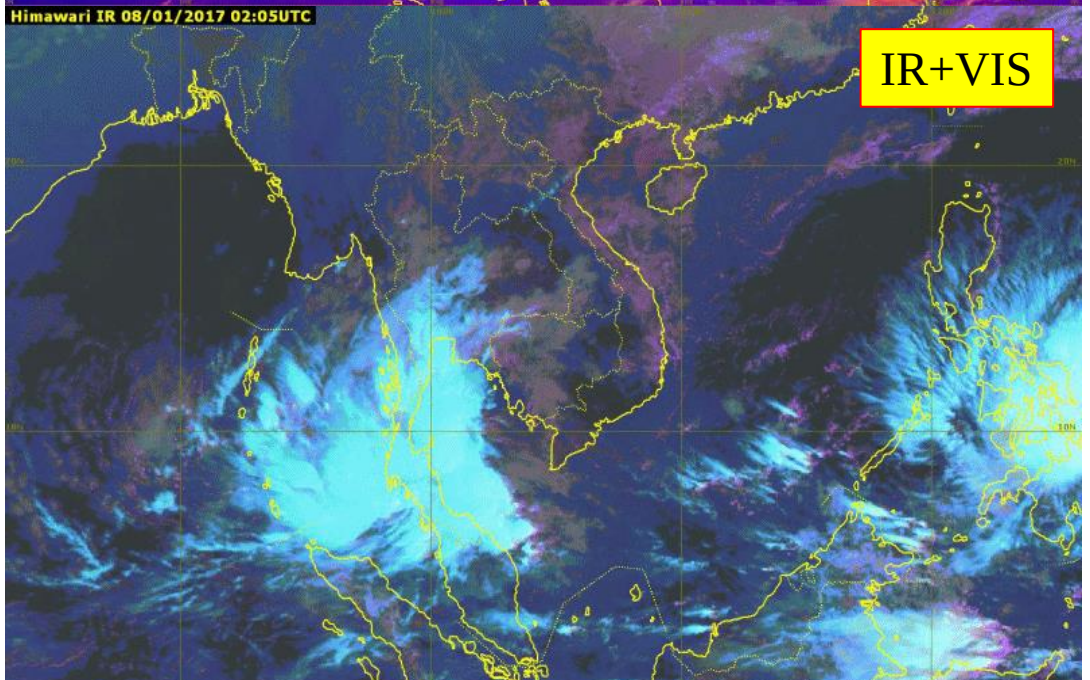


Satellite detection in each channel of sensor to enchant.









2.2 Ground Data

The rain gauge stations network of Thai Meteorological Department (TMD) compose of the surface stations, Agro-meteorological stations and Hydro-meteorological stations about 126 Stations measuring in every hour.

AWS

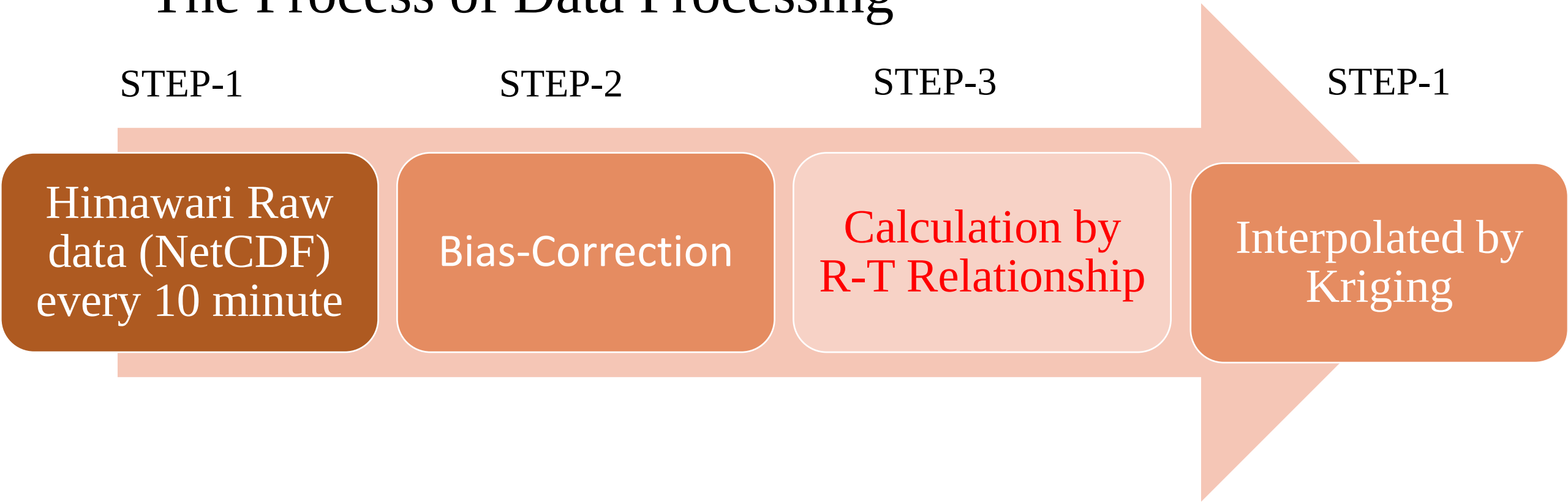
AWS

Meteorology Field

3. Methodology

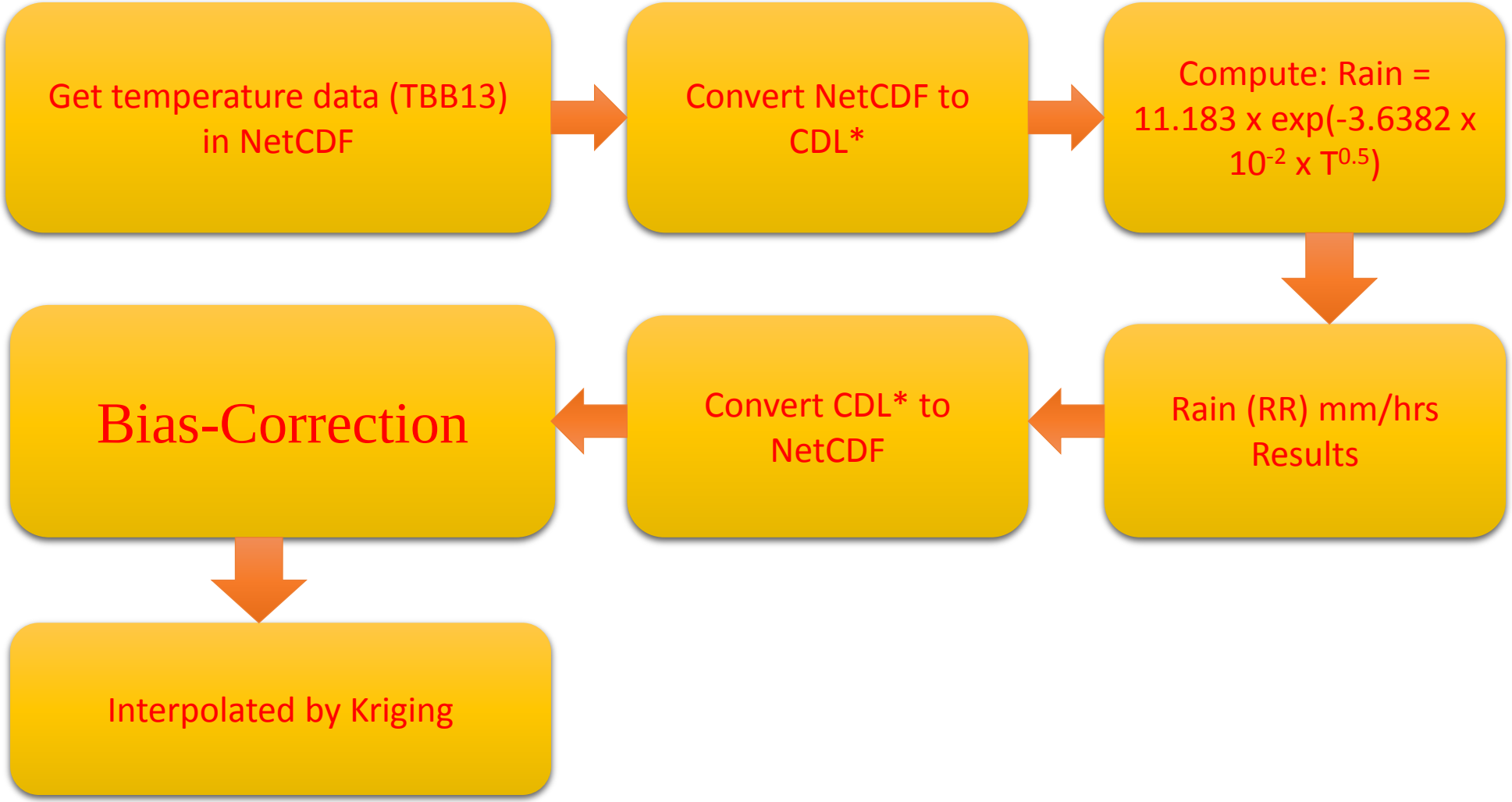
Data Processing

- The Process of Data Processing



3. Methodology (Cont.)

Flowchart



*CDL: Network Common Data form Description Language

3. Methodology (Cont.)

3.1 Precipitation Rate Equation

The original equation modified the brightness temperature according to the convective equilibrium level temperature prior to computing rainfall rate. The estimation rainfall from satellite can compute from the relationship between *rainfall rate* and *temperature* of cloud in infrared band (IR), follow equation 1 (Vicente et al. 1998).

$$R = 1.183 \times 10^{11} \exp(-0.036382 \times T^{0.5}) \quad (1)$$

Where R is the rainfall rate in mm/h and T is temperature in *Kelvin*.

3.2 Bias correction methodology

The bias correction with five methods and two schemes were used in this study to produce improvement products. The accuracy of each product was assessed at time scale by comparing with the rain gauges. Five bias correction techniques were used to compare bias corrected satellite rainfall data to respect with rain gauge rainfall data. Description of the bias correction techniques is presented in following sections. Main variable of the bias correction is *R* (rain observation) and *S* (rainfall from satellite). The corrected data was firstly adjusted by finding the mean ratio between rain gauge and satellite (Ines and Hansen, 2006; Acharya et al., 2013; Aws et al., 2015). As shown in equation 2. The ratio vale is calculated in the cross validation method. The advantage of this technique is that the bias value is removed from mean, while its disadvantage is to fail in correction of rainfall intensity.

$$R_i = \frac{\bar{R}}{\bar{S}} S_i \qquad (2)$$

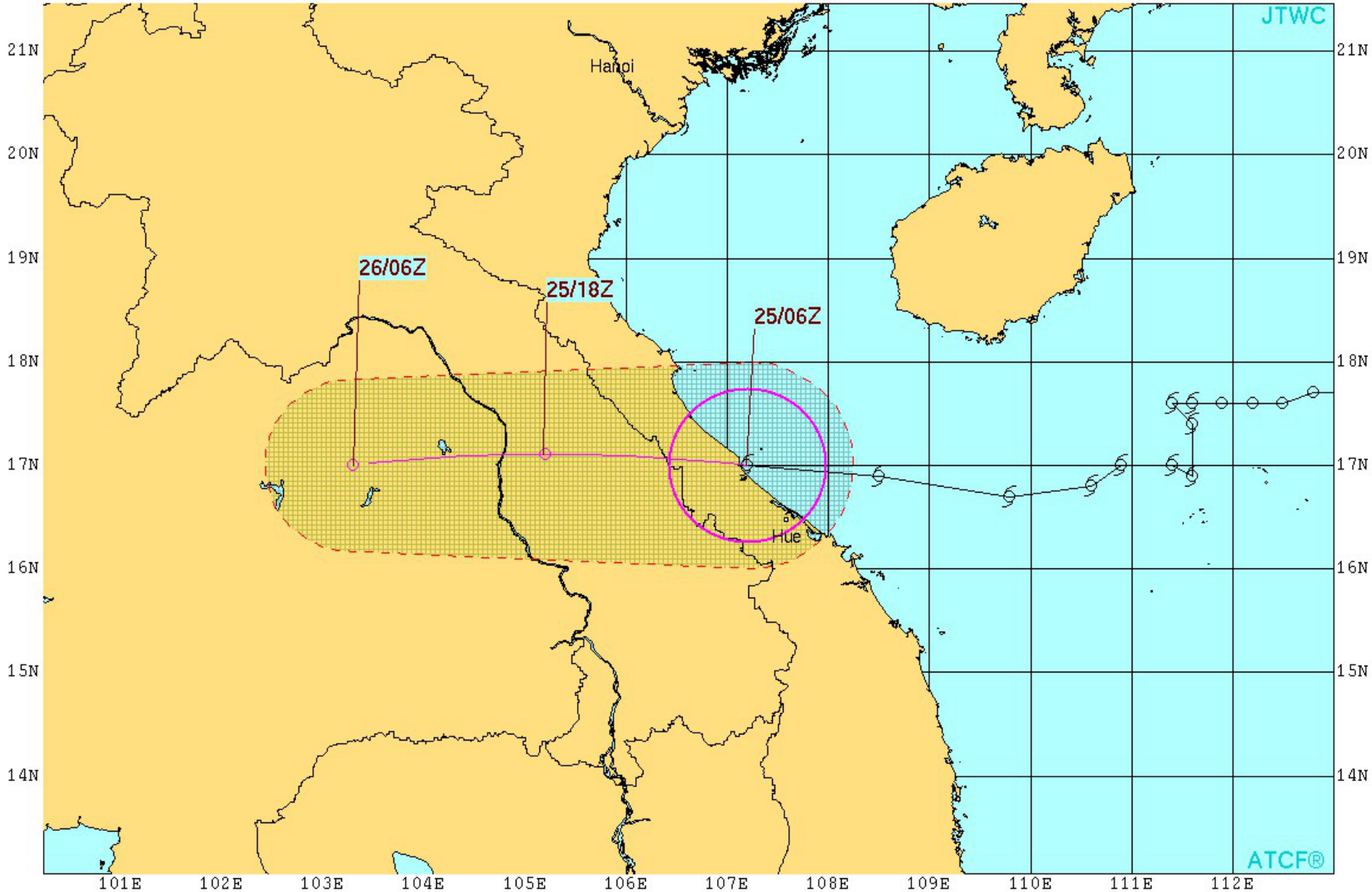
3.3 Kriging Interpolated method

Kriging is a family of estimators used to interpolate spatial data. This family includes:

- O**rdinary Kriging**,
- Universal K**riging**,
- Indicator **Kriging**,
- Co-**Kriging** and others. ...

Universal **Kriging** is used to estimate spatial means when the data have a strong trend and the trend can be modeled by simple functions.

Tropical Storm “SONCA” track, 26-30 July 2017



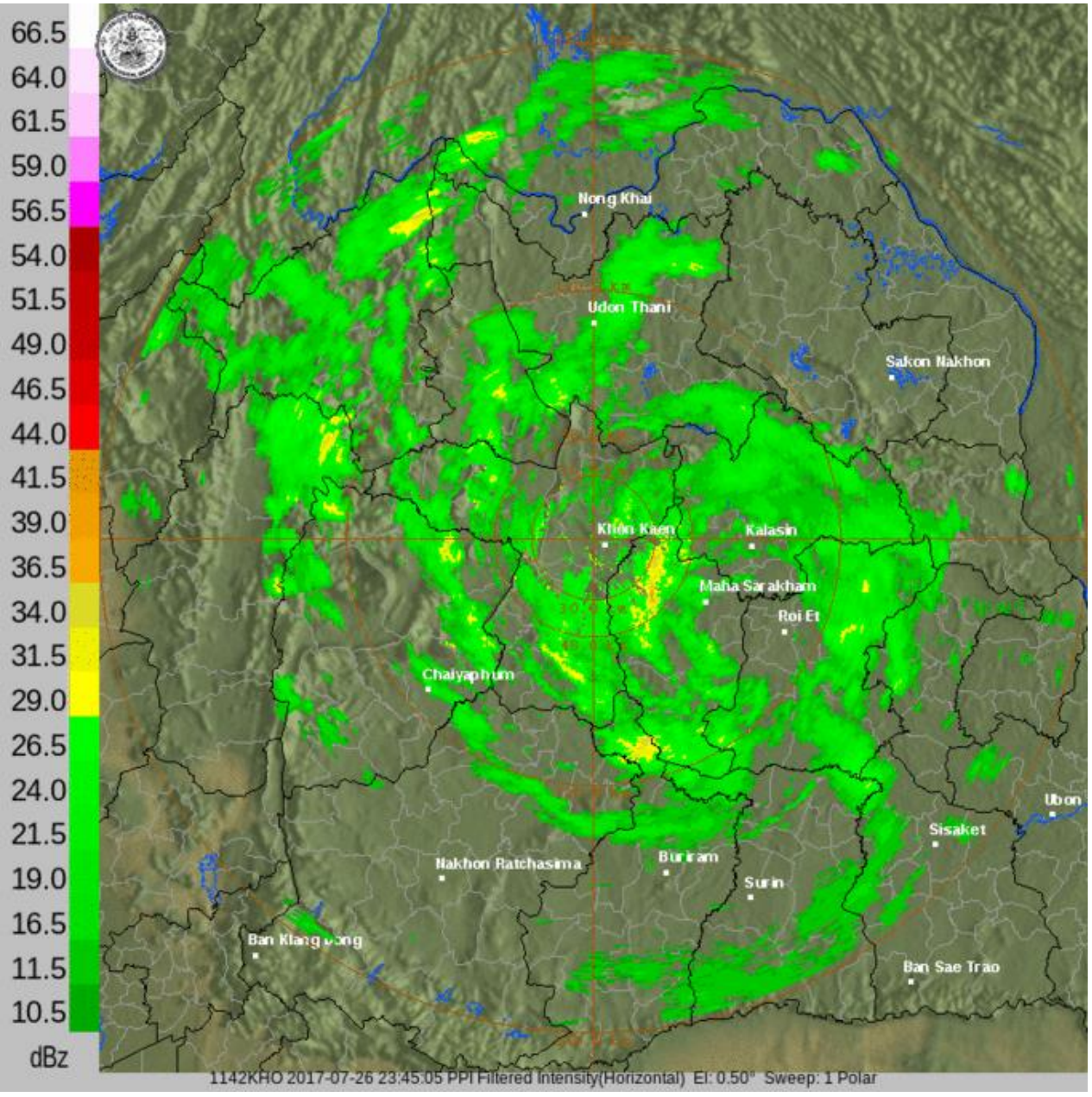
TROPICAL STORM 08W (SONCA) WARNING #18
*** FINAL WARNING ***
WTPN32 PGTW 250900
250600Z POSIT: NEAR 17.0N 107.2E
MOVING 275 DEGREES TRUE AT 12 KNOTS
MAXIMUM SIGNIFICANT WAVE HEIGHT: 12 FEET
25/06Z, WINDS 040 KTS, GUSTS TO 050 KTS
25/18Z, WINDS 030 KTS, GUSTS TO 040 KTS
26/06Z, WINDS 020 KTS, GUSTS TO 030 KTS

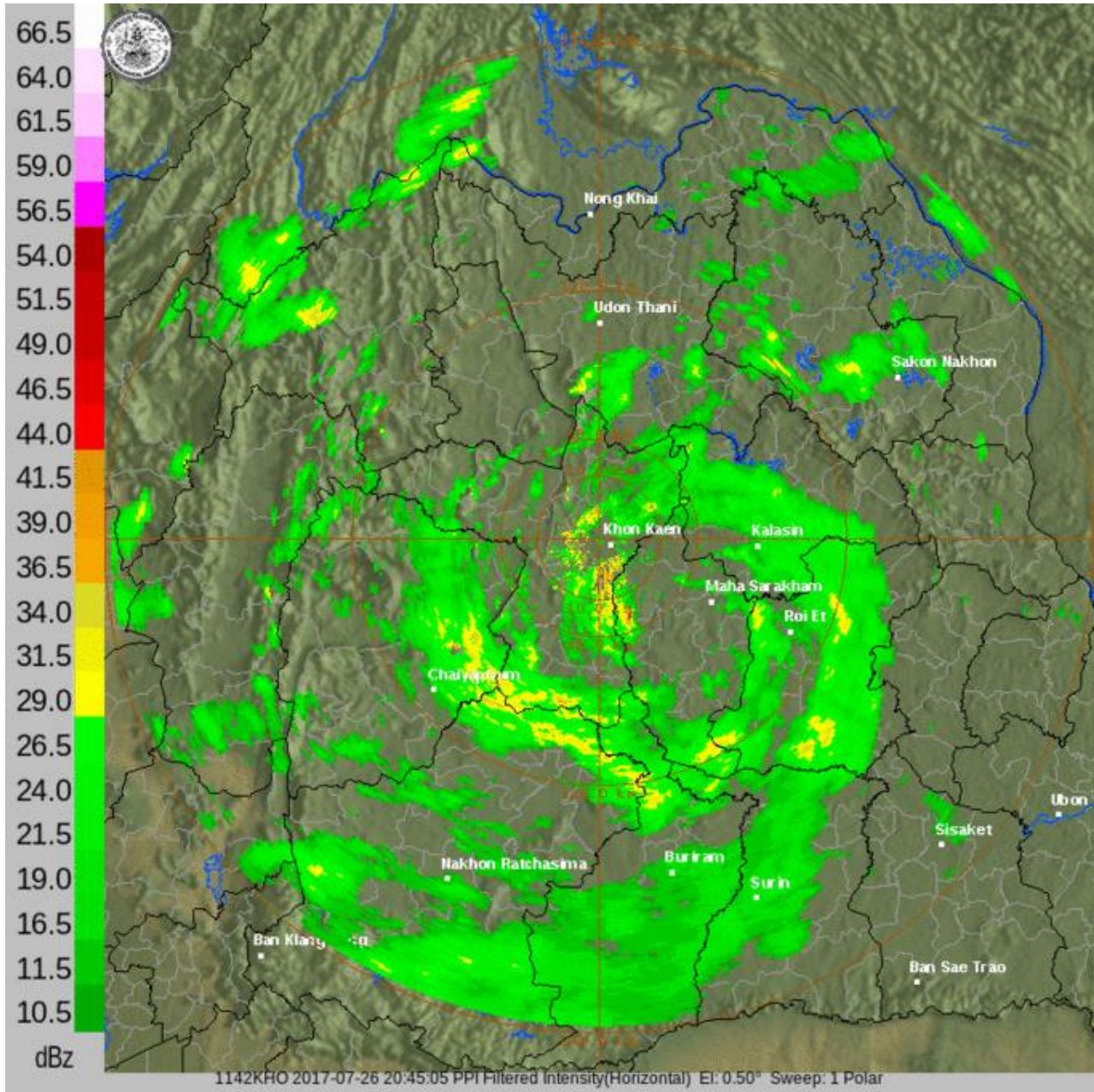
CPA TO:	NM	DTG
HO_CHI_MINH_CITY	372	25/08Z
HANOI	236	25/16Z

BEARING AND DISTANCE	DIR	DIST (NM)	TAU (HRS)
DA_NANG	314	87	0
HANOI	163	251	0
HO_CHI_MINH_CITY	004	373	0

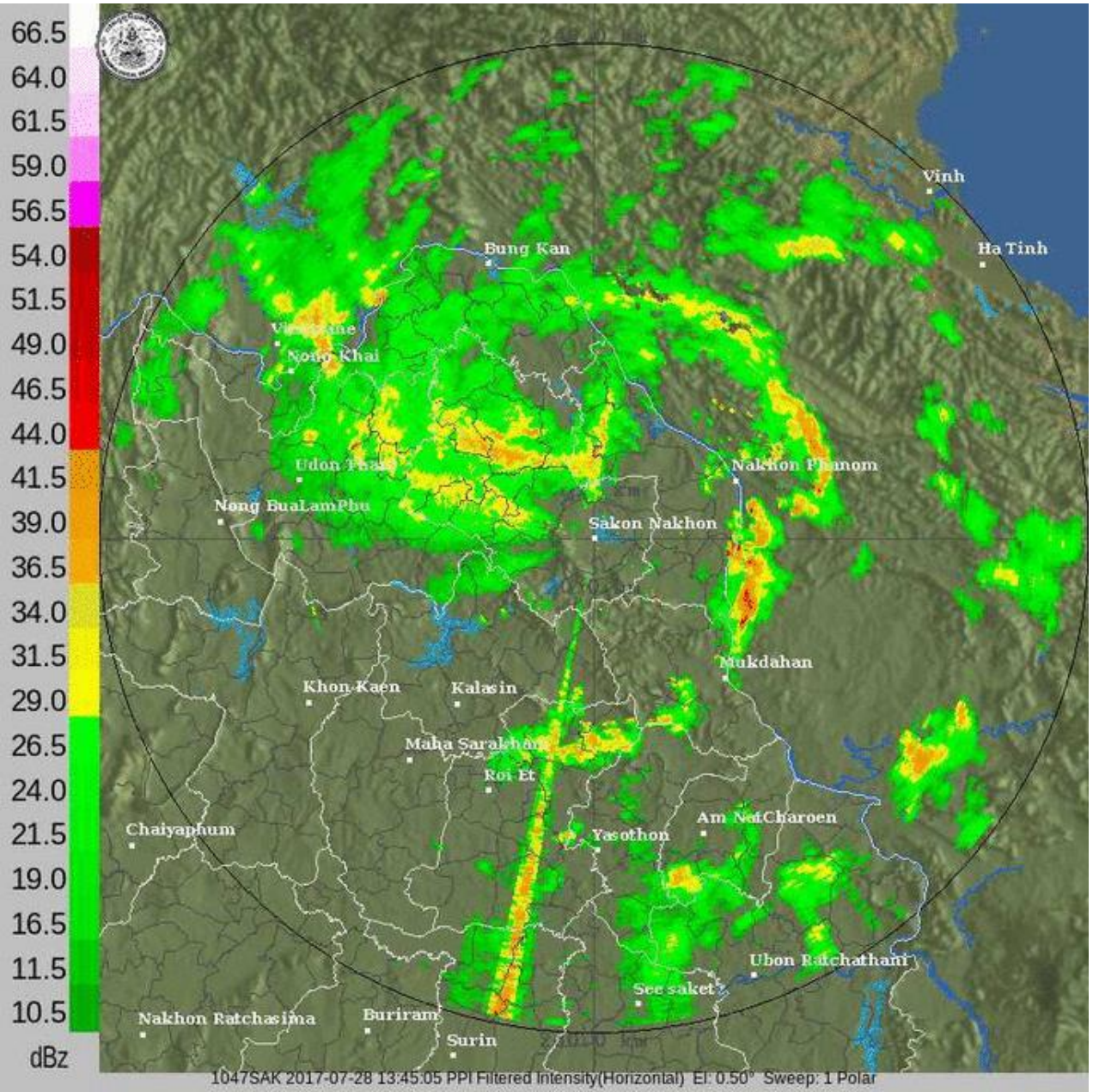
LESS THAN 34 KNOTS
34-63 KNOTS
MORE THAN 63 KNOTS
PAST 6 HOURLY CYCLONE POSITS IN BLACK
FORECAST CYCLONE POSITS IN COLOR

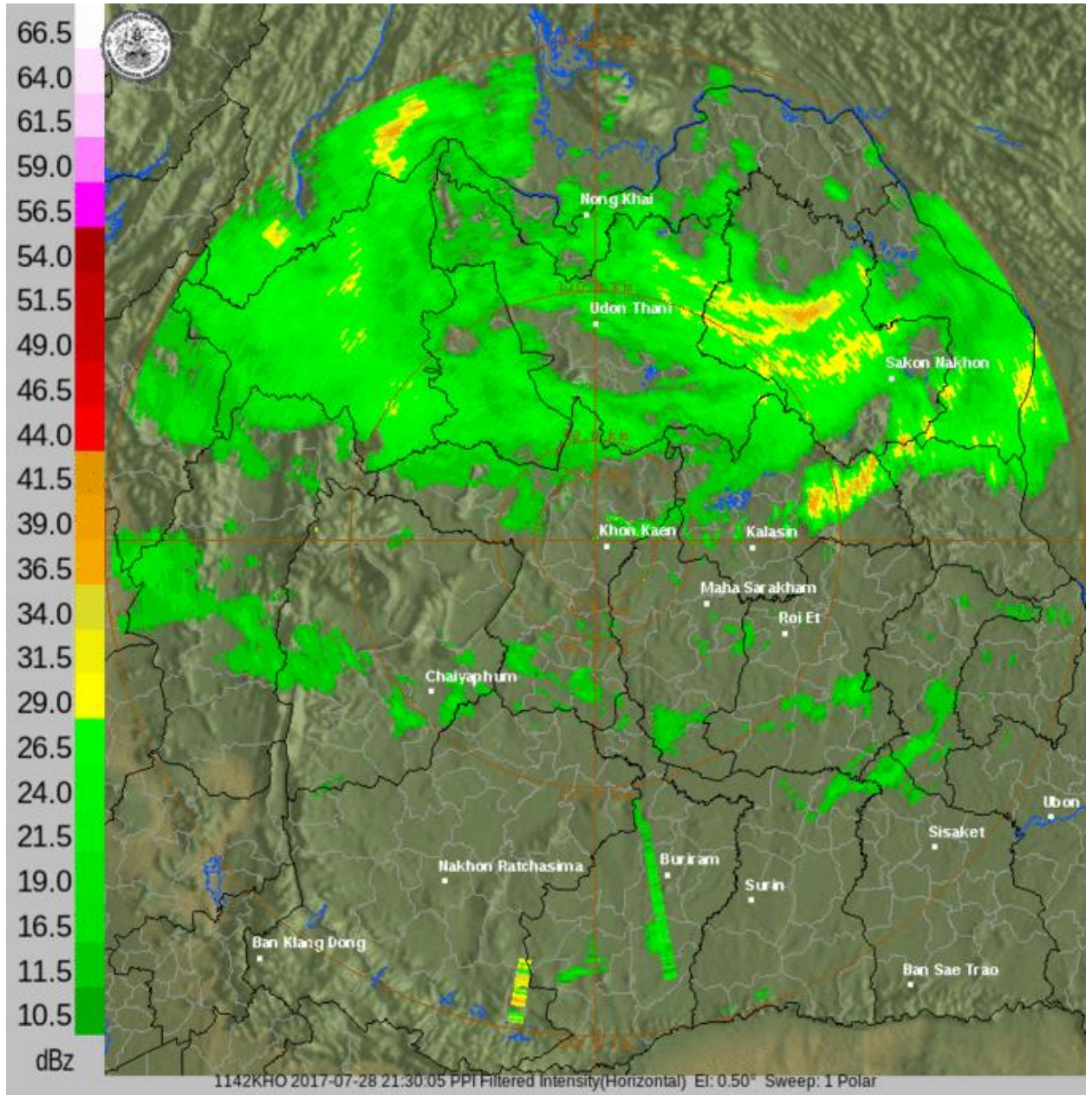
Weather Radar Khon Kean Sta. detected echo precipitation over the Area



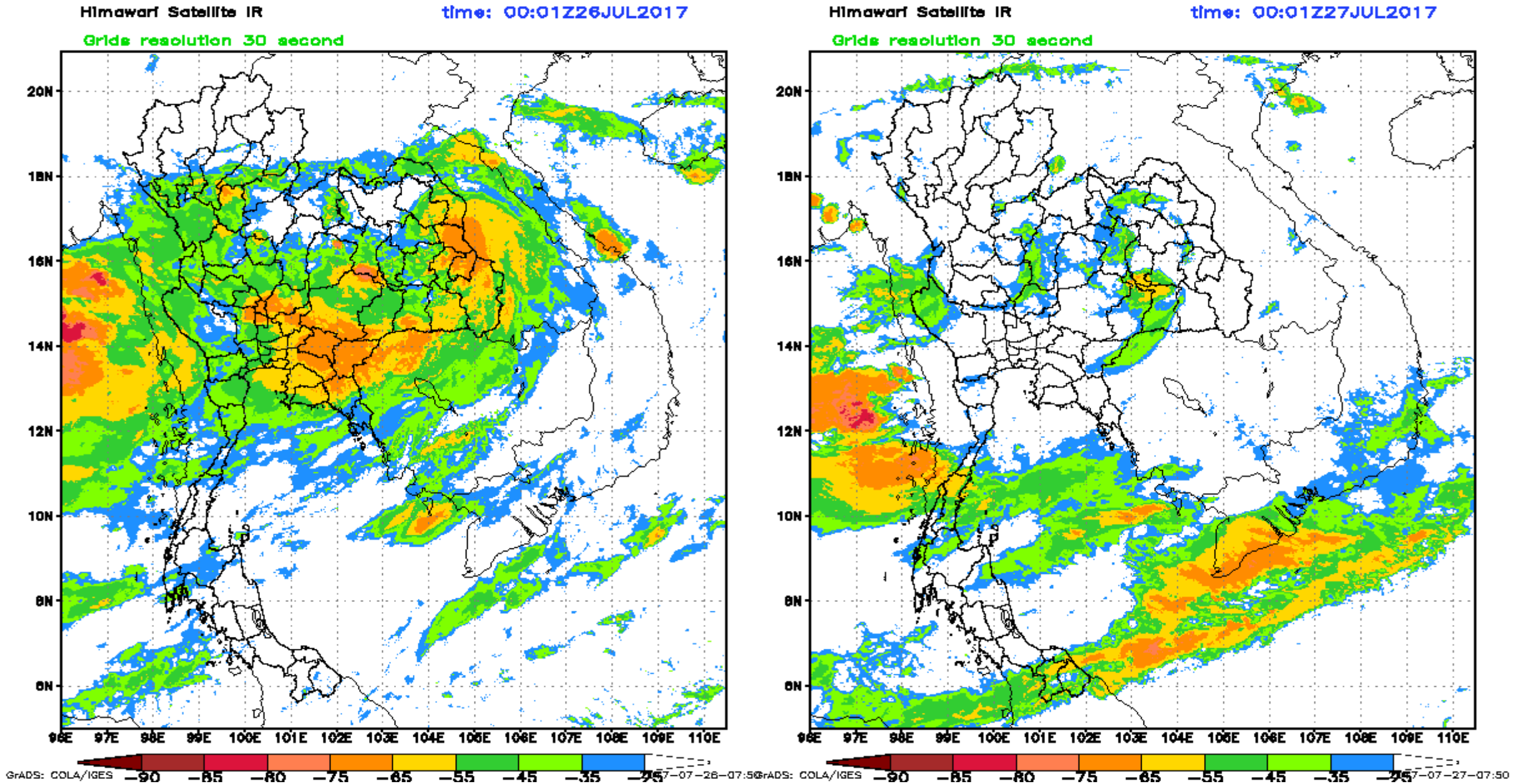


Weather Radar Khon Kean Sta. detected echo precipitation over the Area



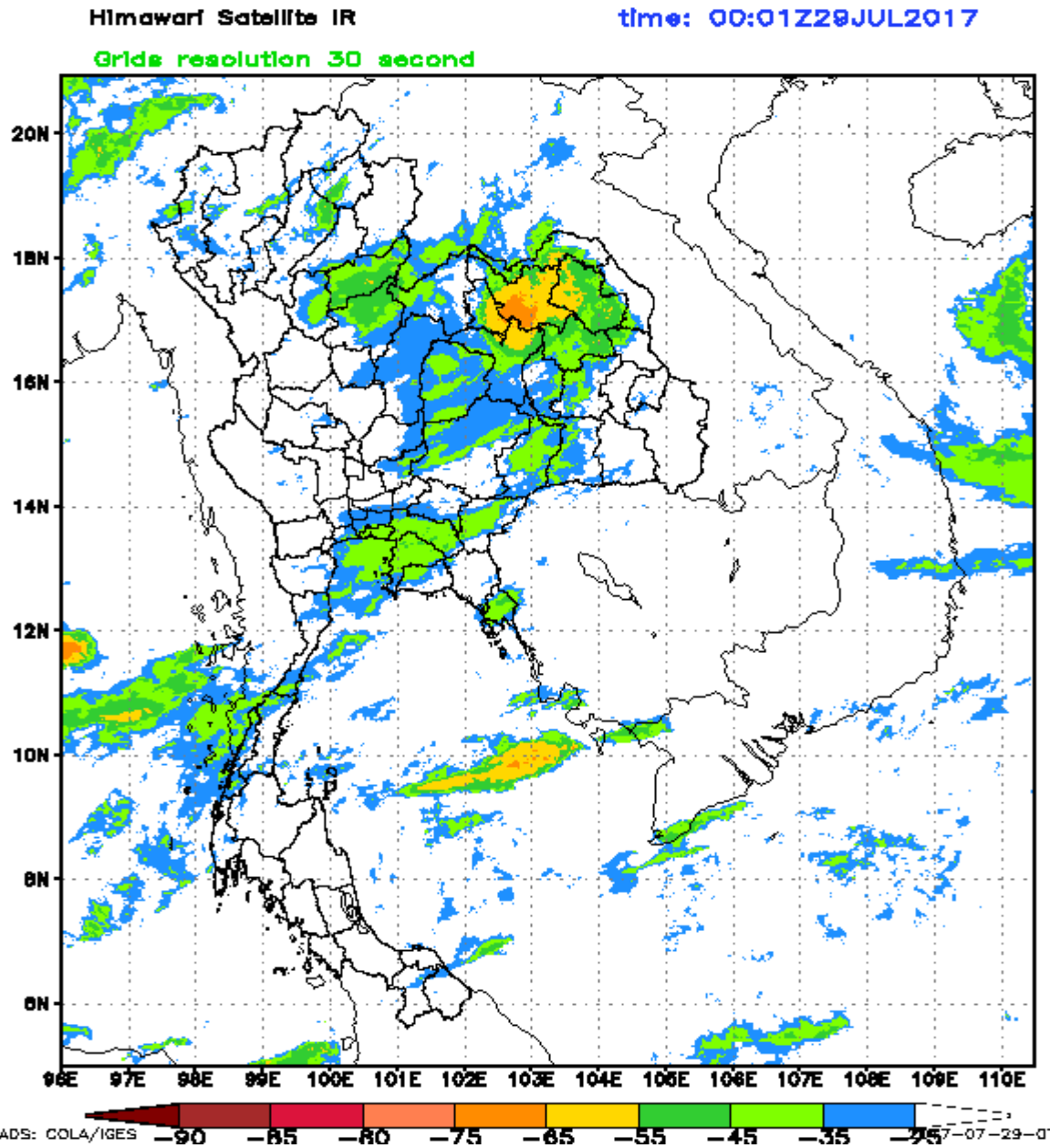


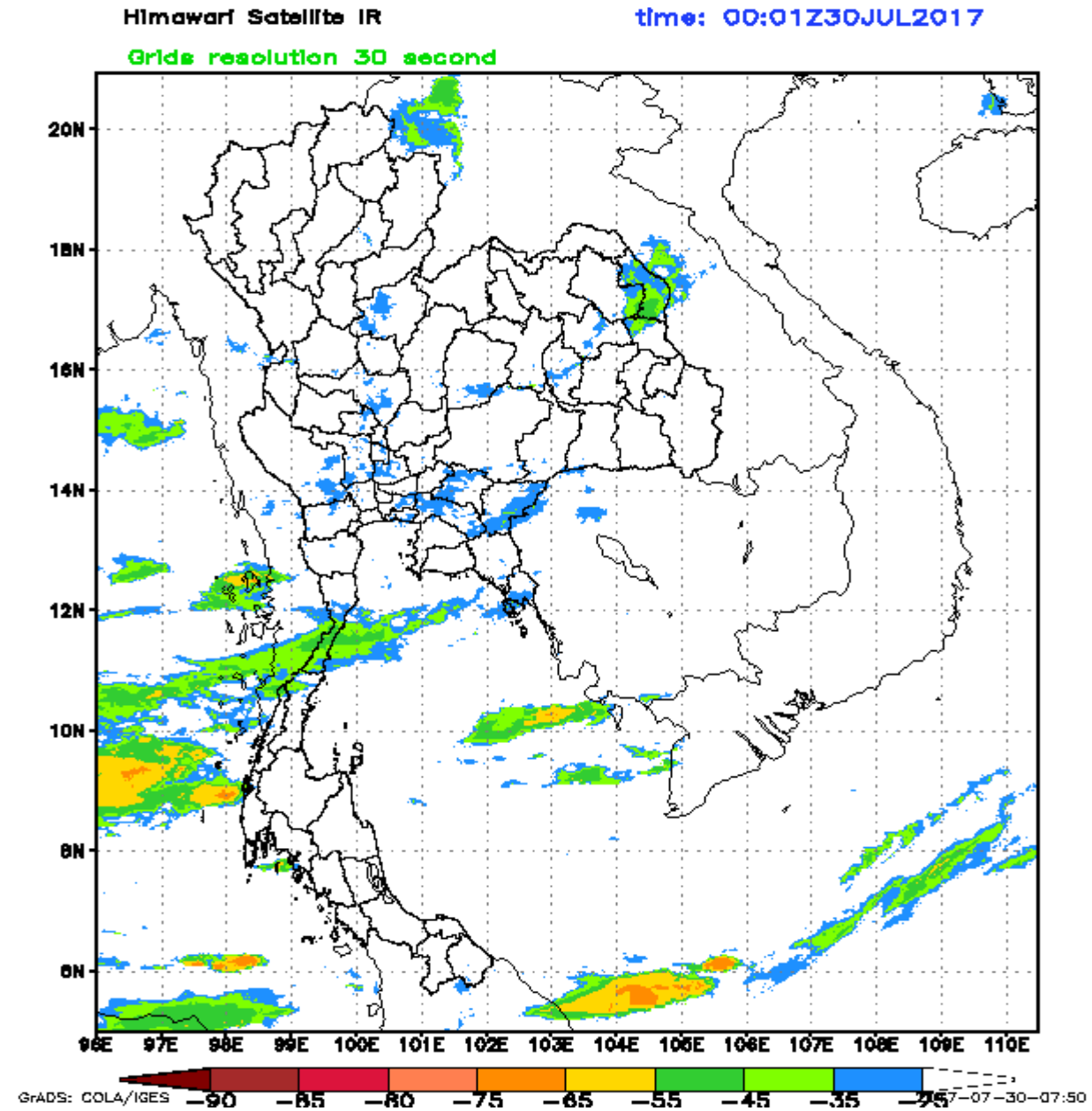
Temperature of Clouds detected which was IR-13



www.satda.tmd.go.th/animation/himawari.php?date=201707

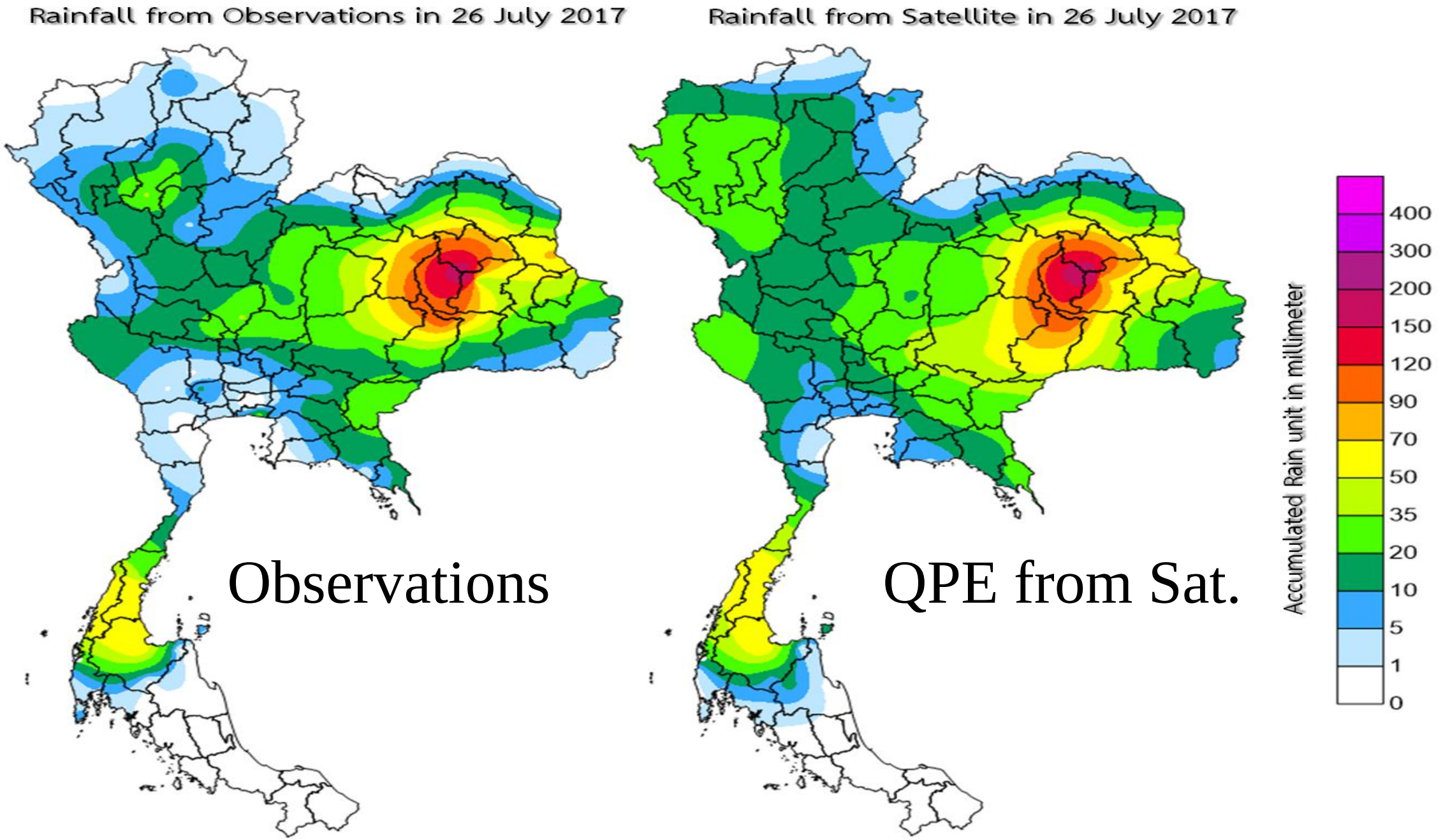
Temperature of Clouds detected which was IR-13



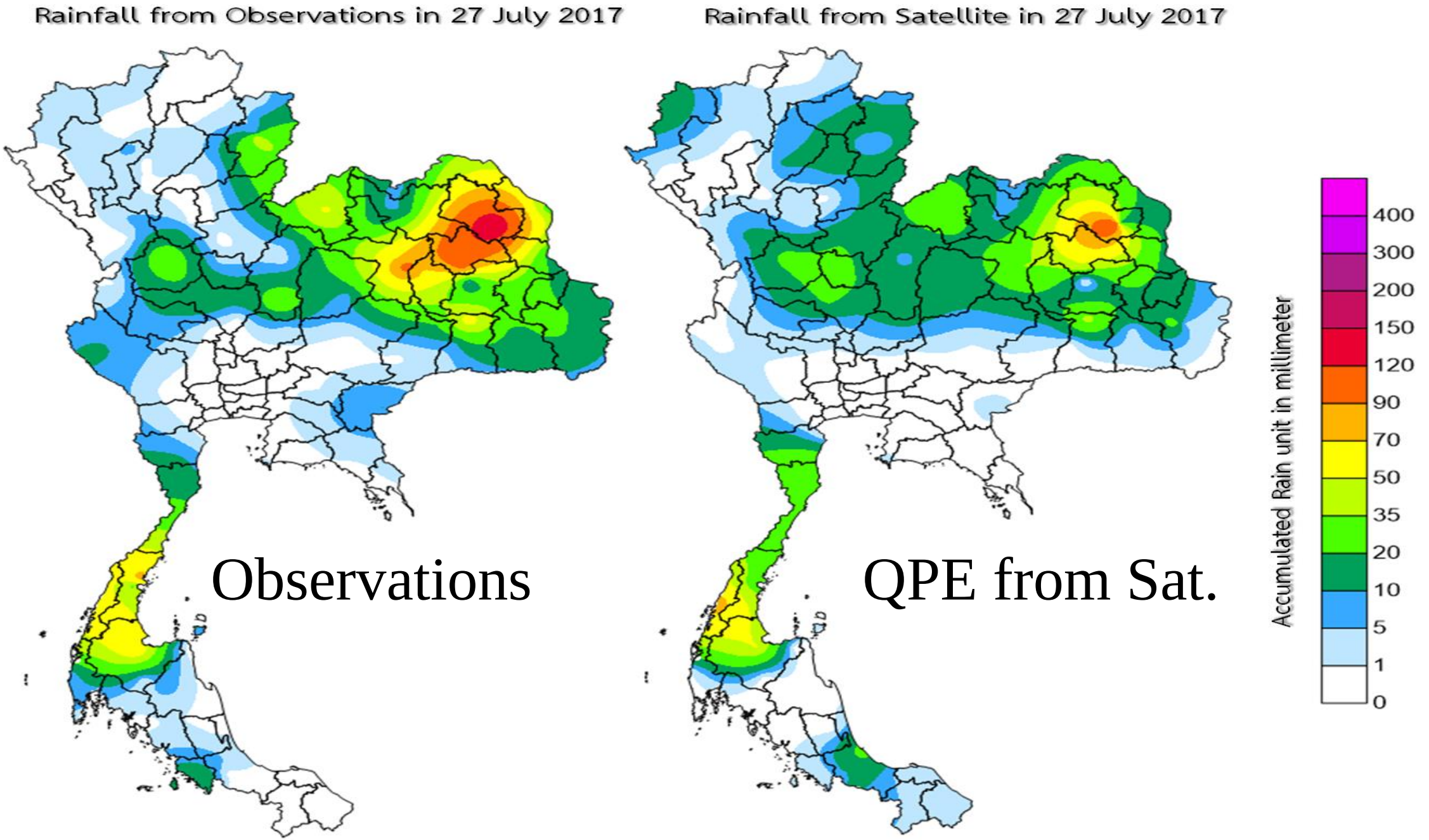


www.satda.tmd.go.th/animation/himawari.php?date=201707

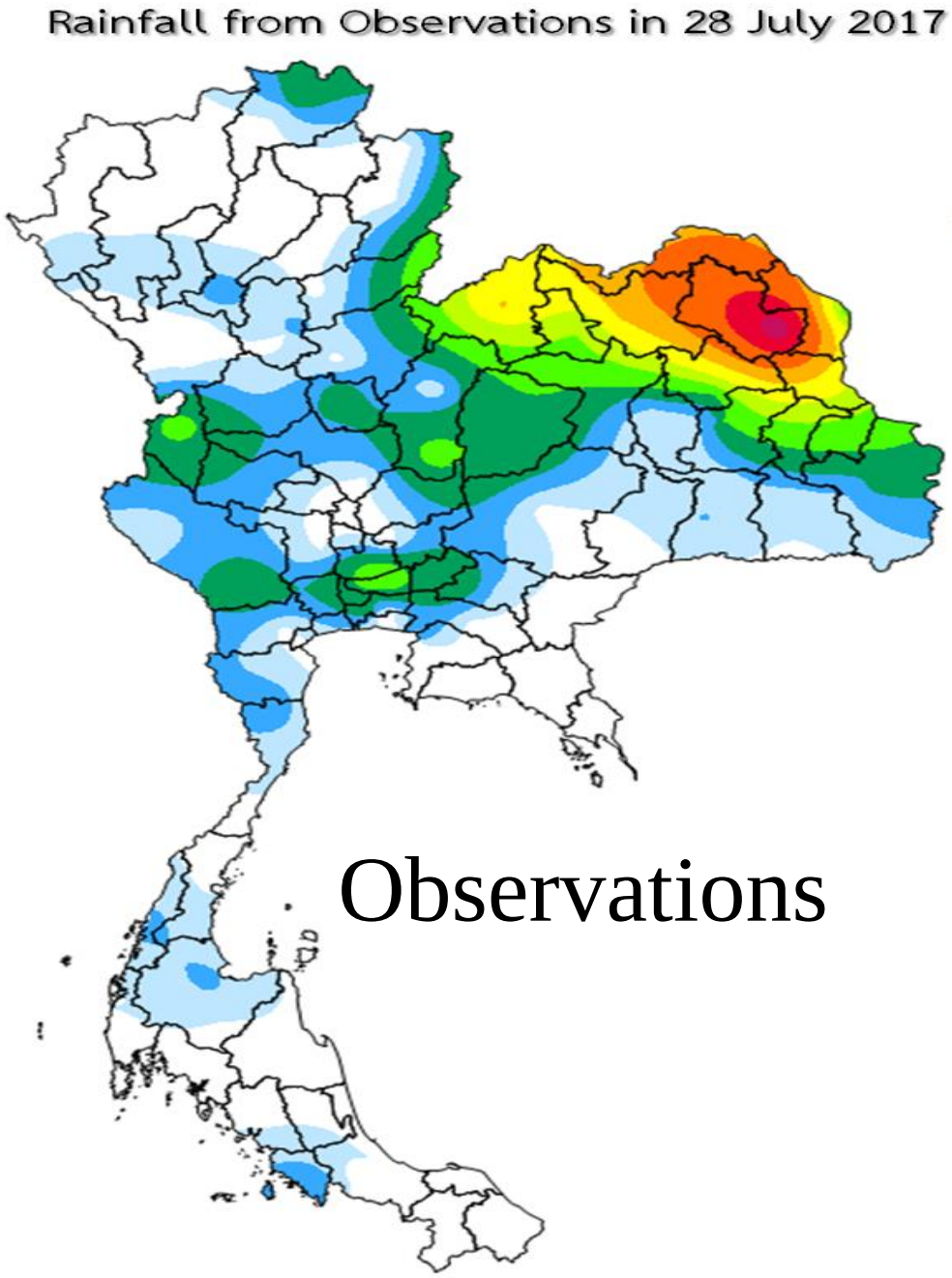
Comparison rainfall distribution from observations to QPE from satellite.



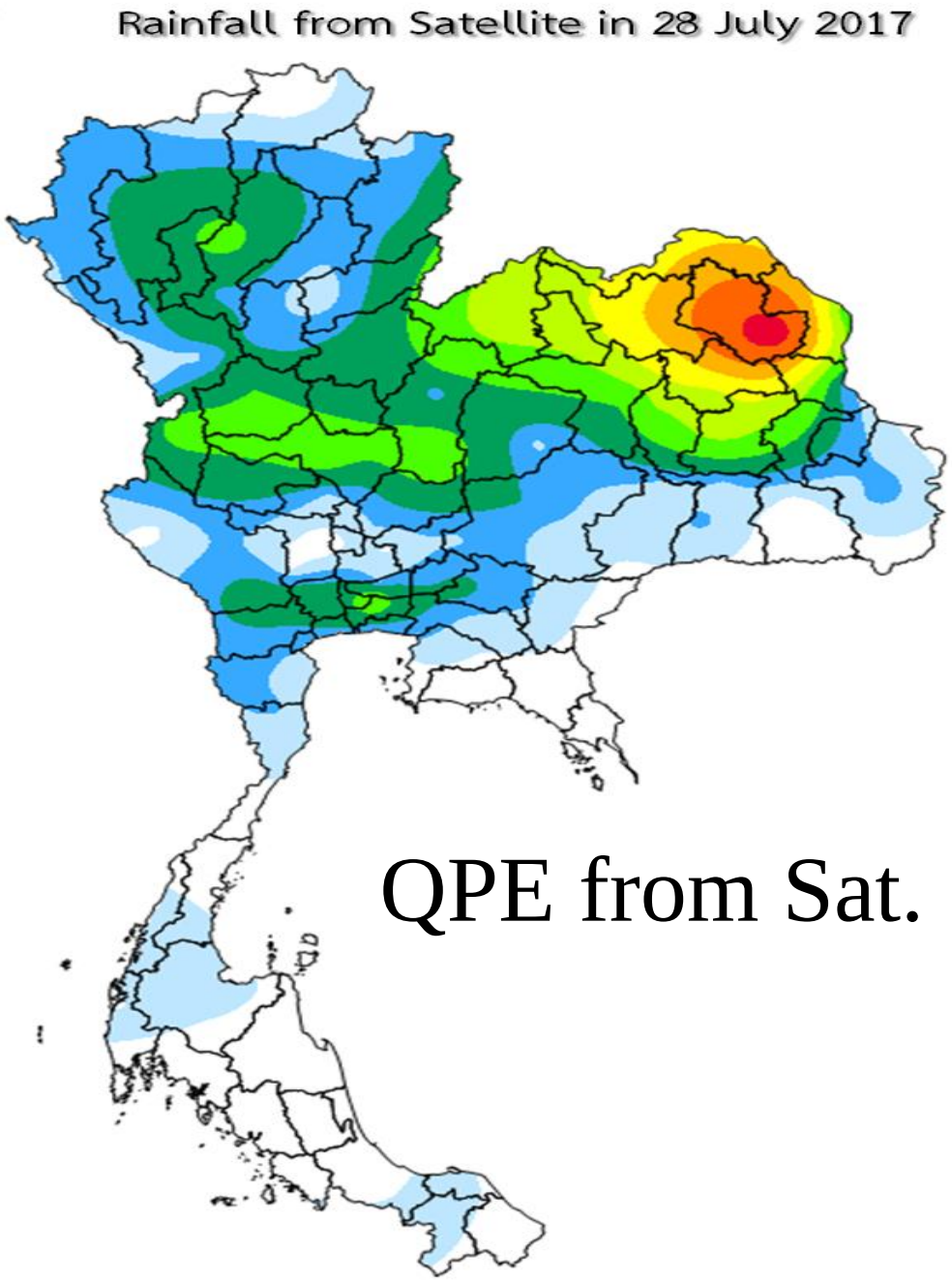
Comparison rainfall distribution from observations to QPE from satellite.



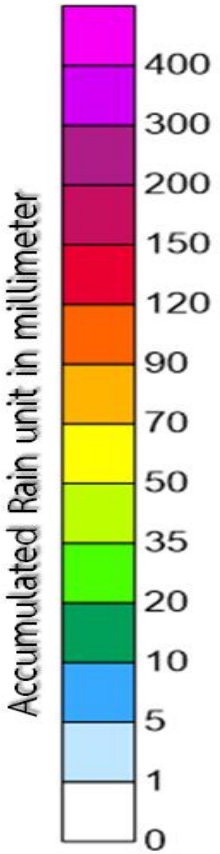
Comparison rainfall distribution from observations to QPE from satellite.



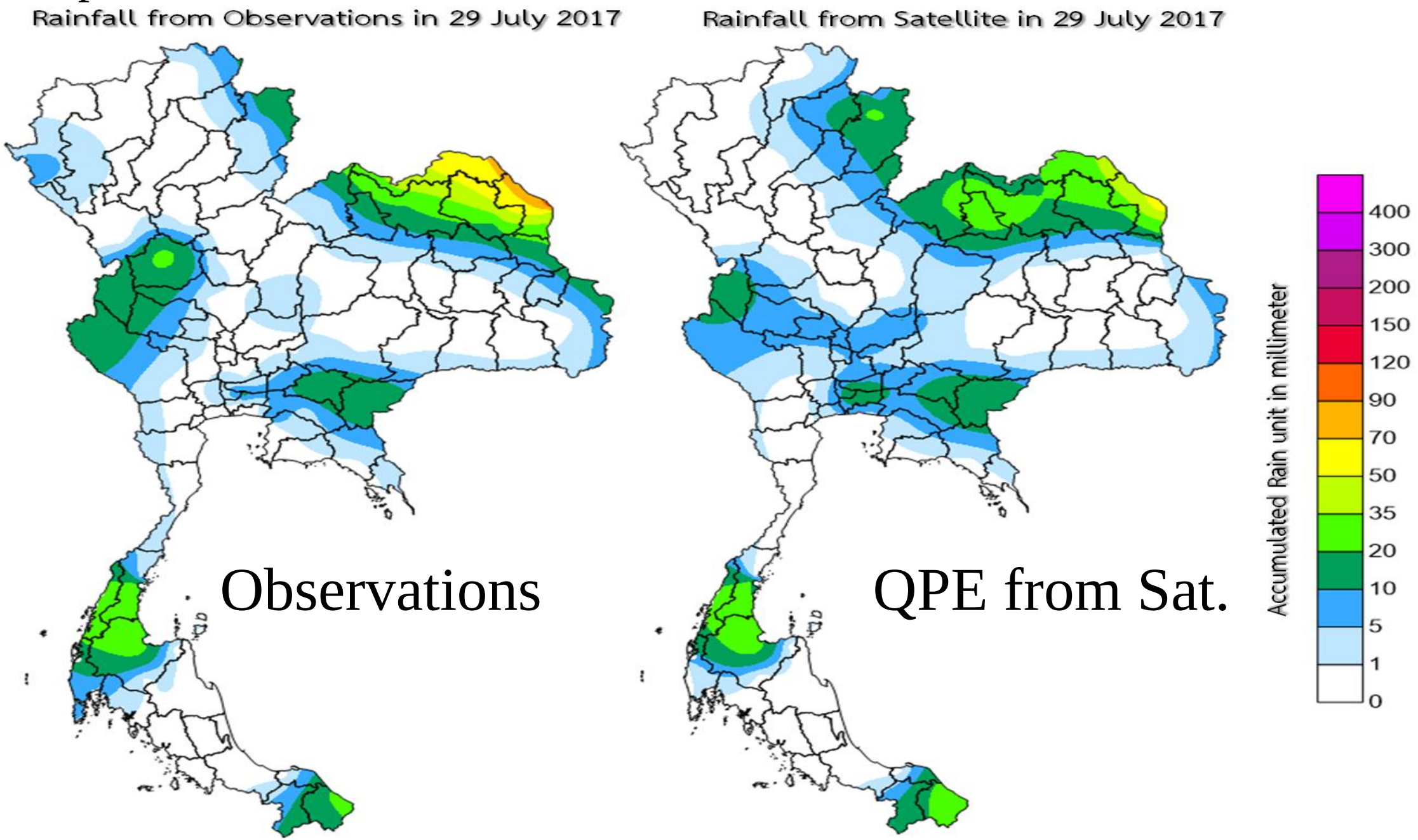
Observations



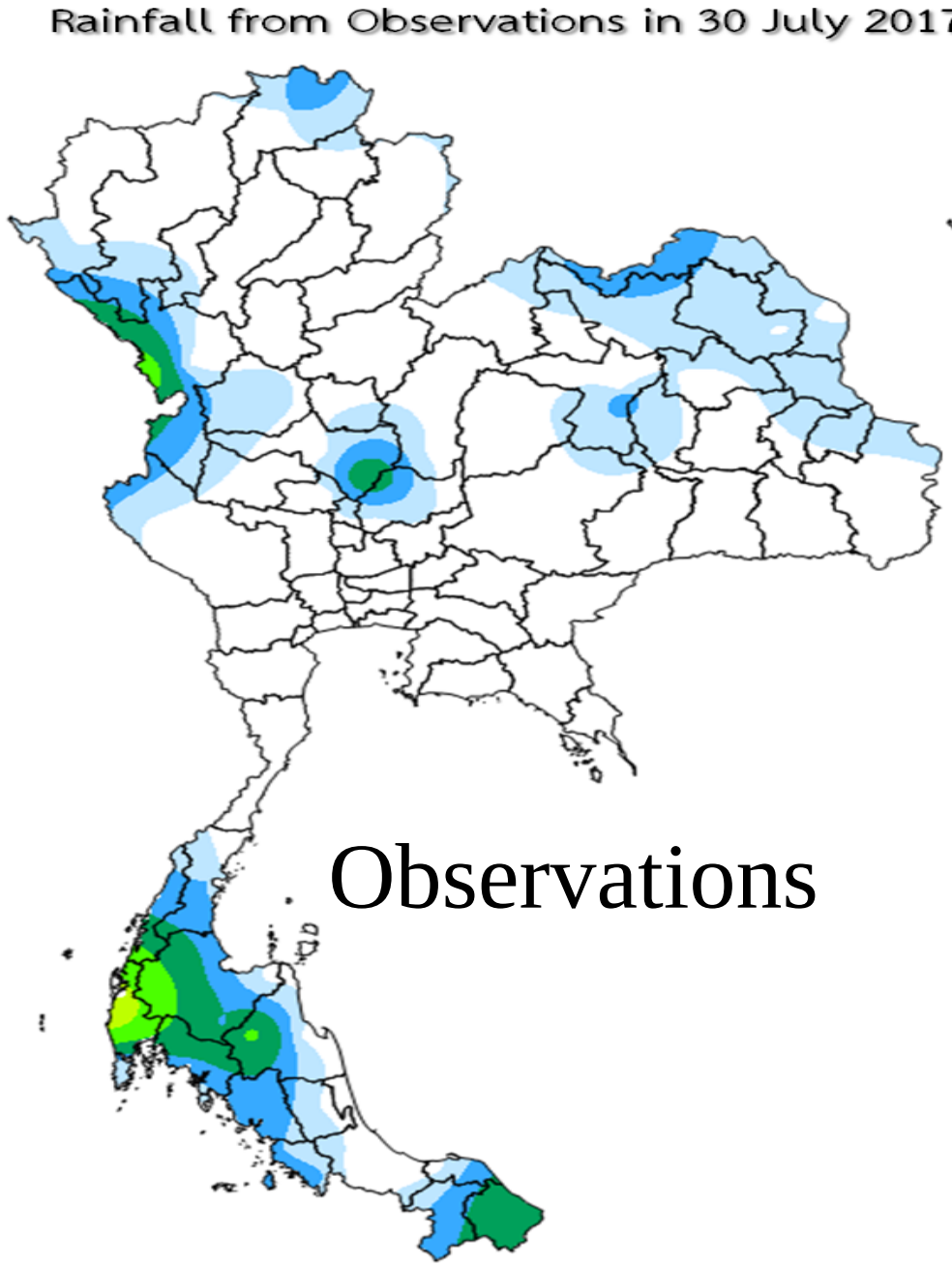
QPE from Sat.



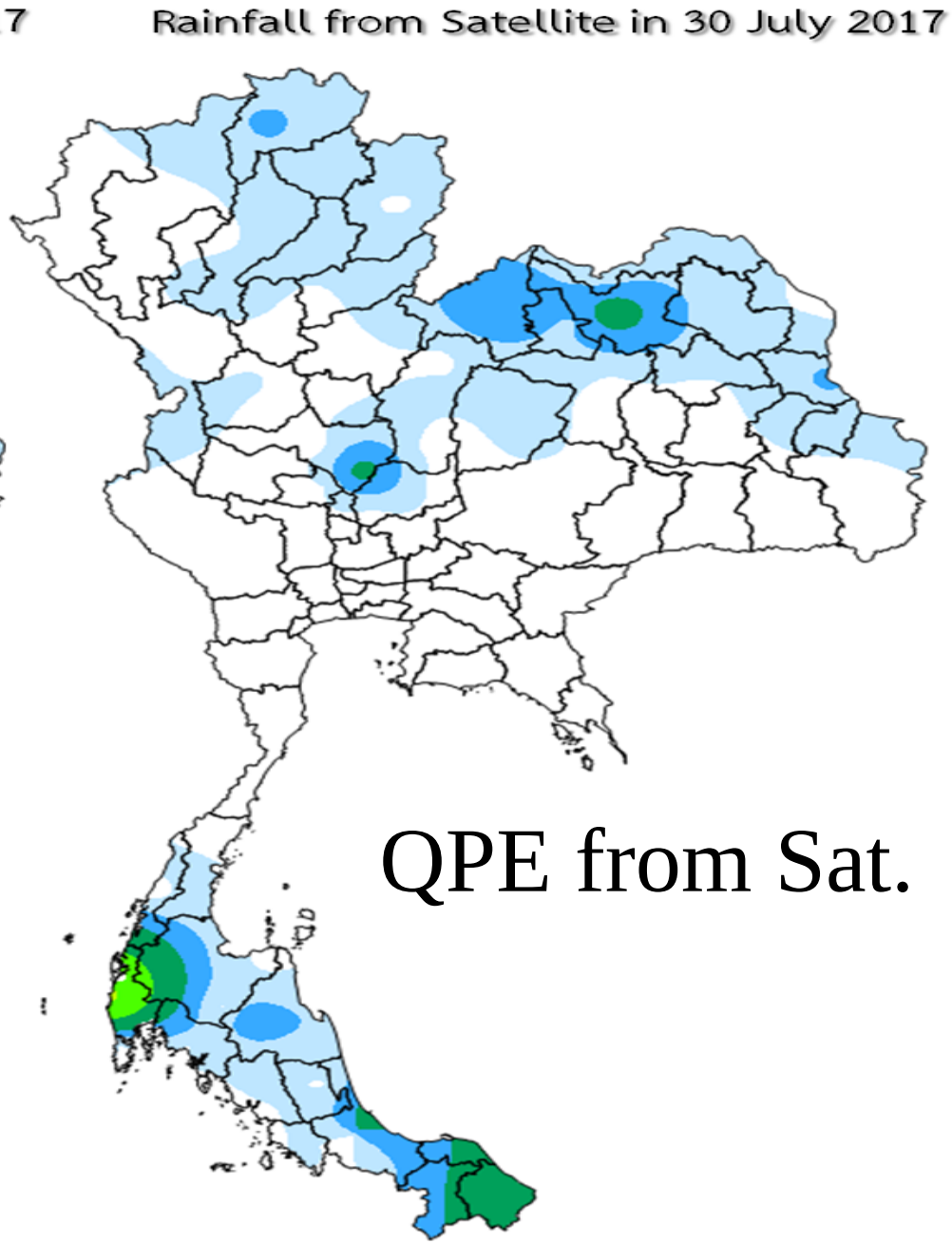
Comparison rainfall distribution from observations to QPE from satellite.



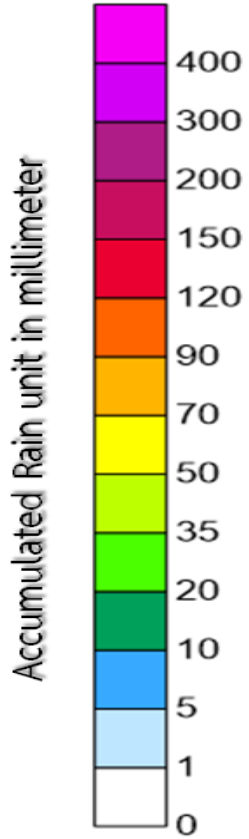
Comparison rainfall distribution from observations to QPE from satellite.



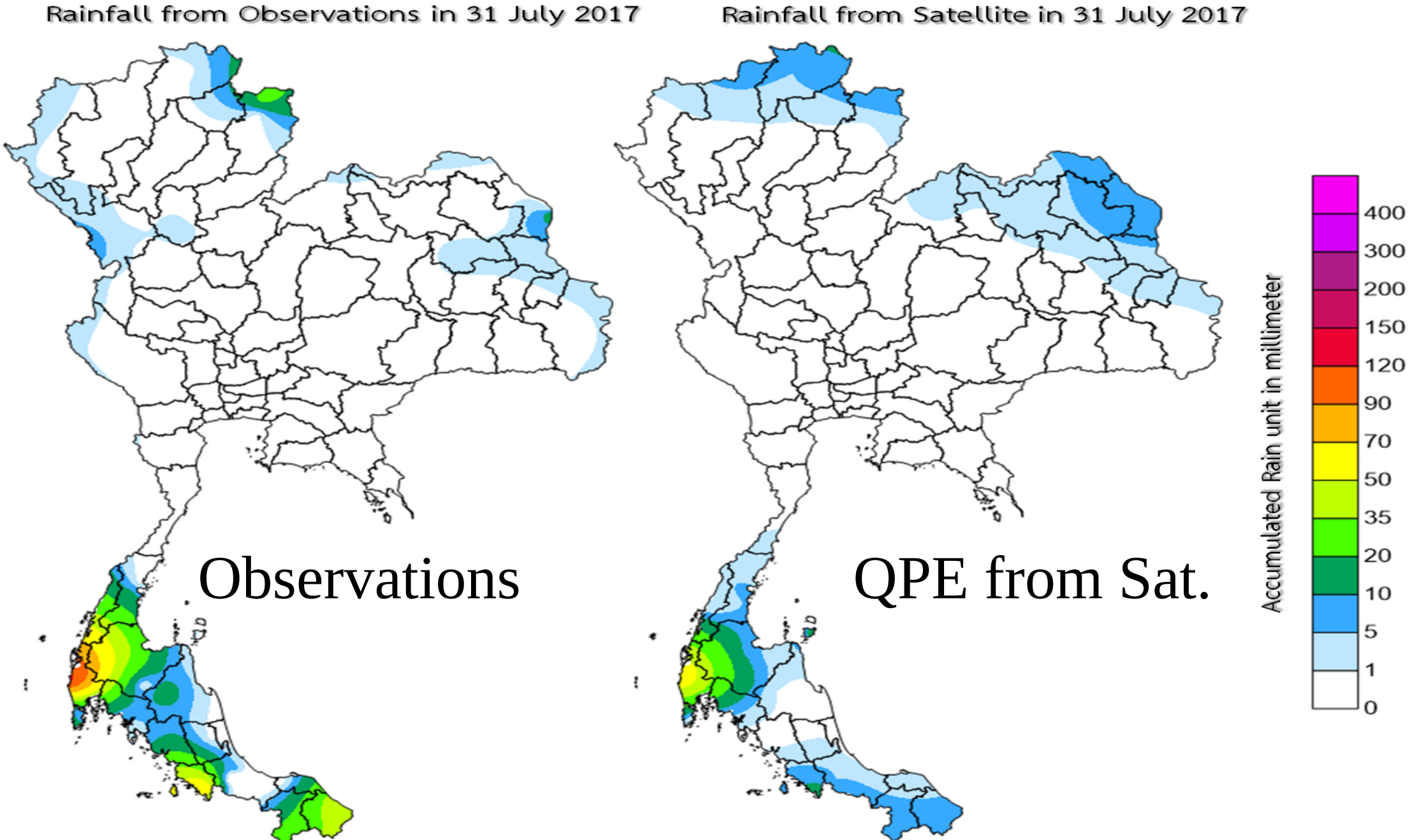
Observations



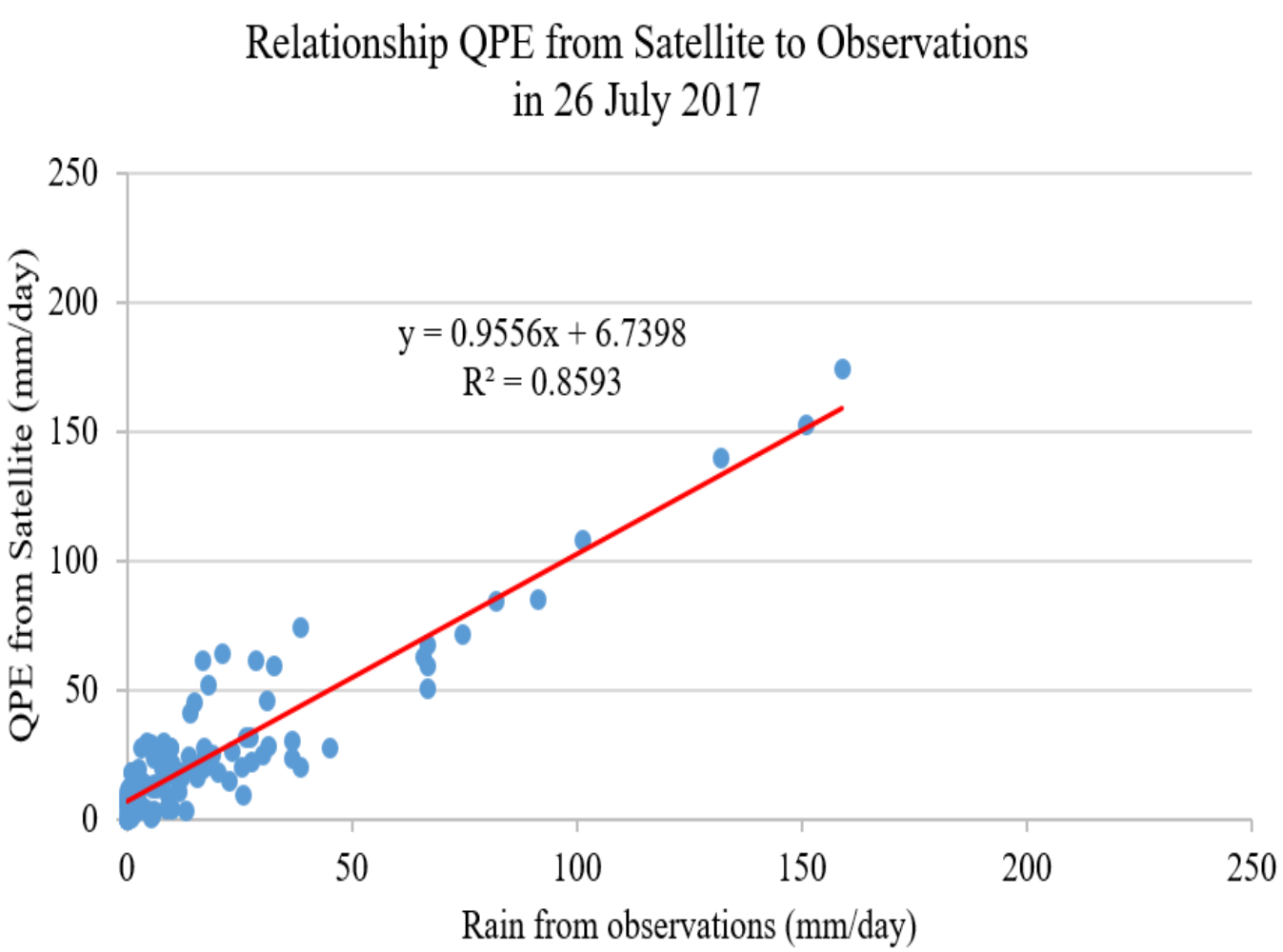
QPE from Sat.

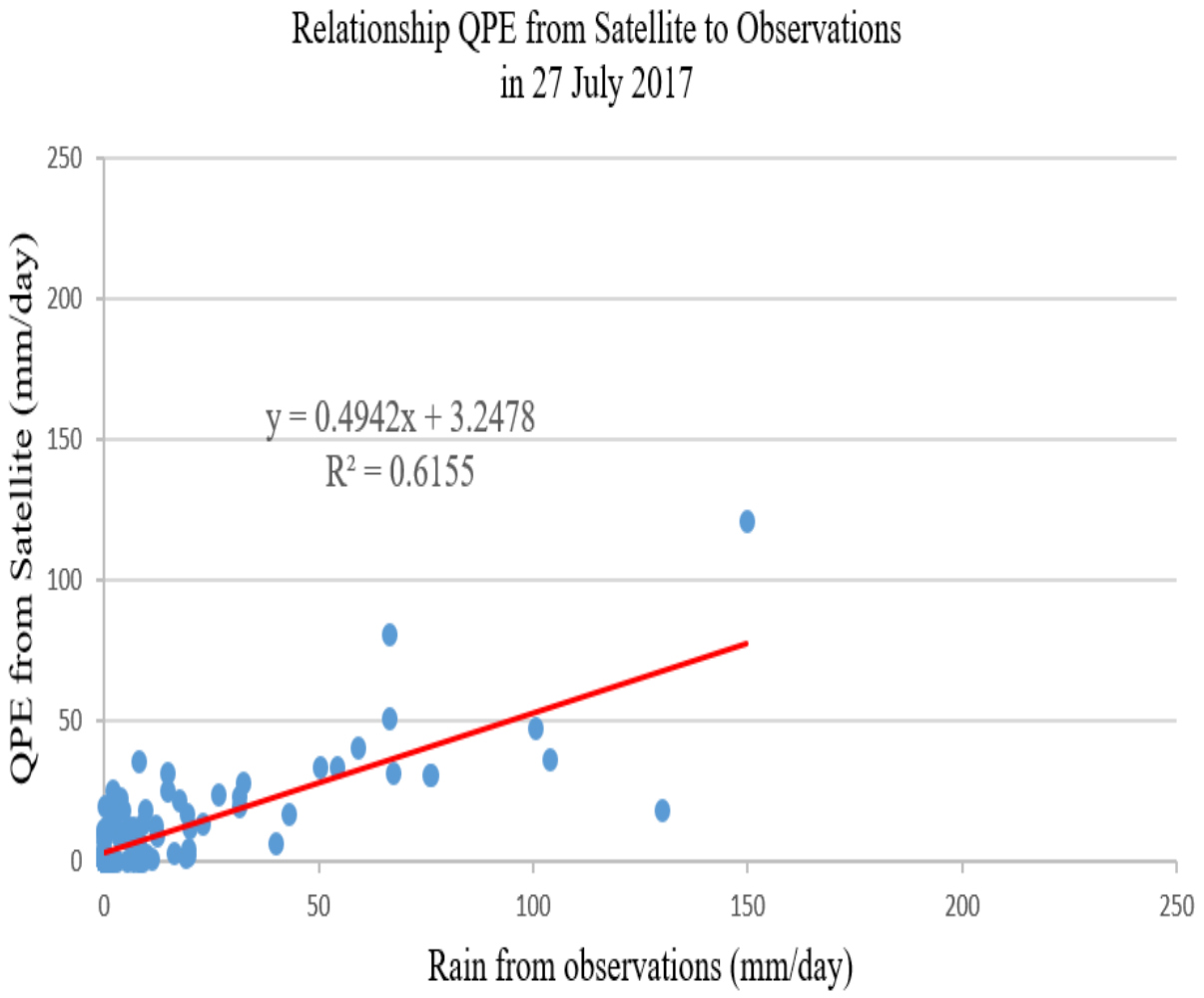


Comparison rainfall distribution from observations to QPE from satellite.

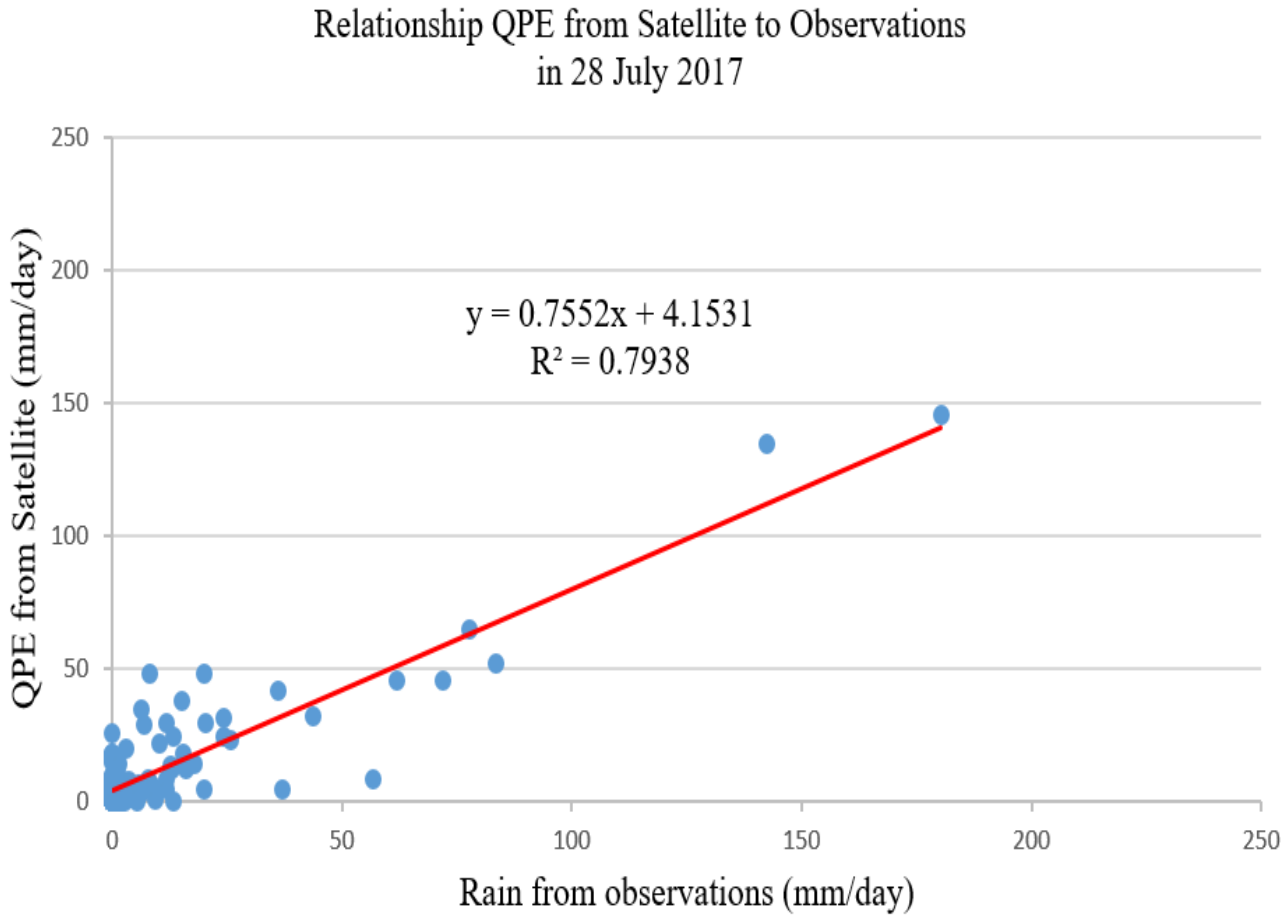


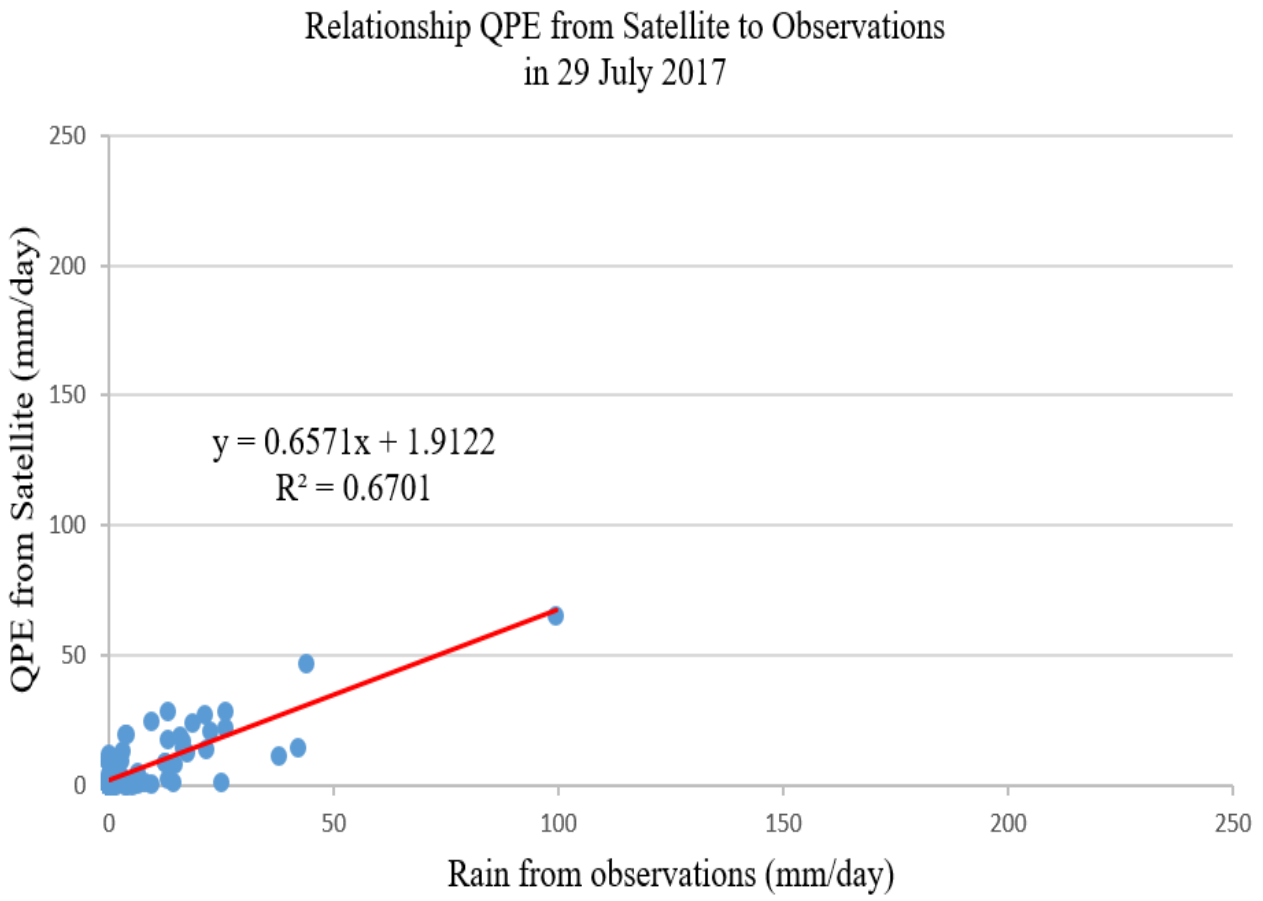
The relation rainfall distribution from QPE from satellite to observations.



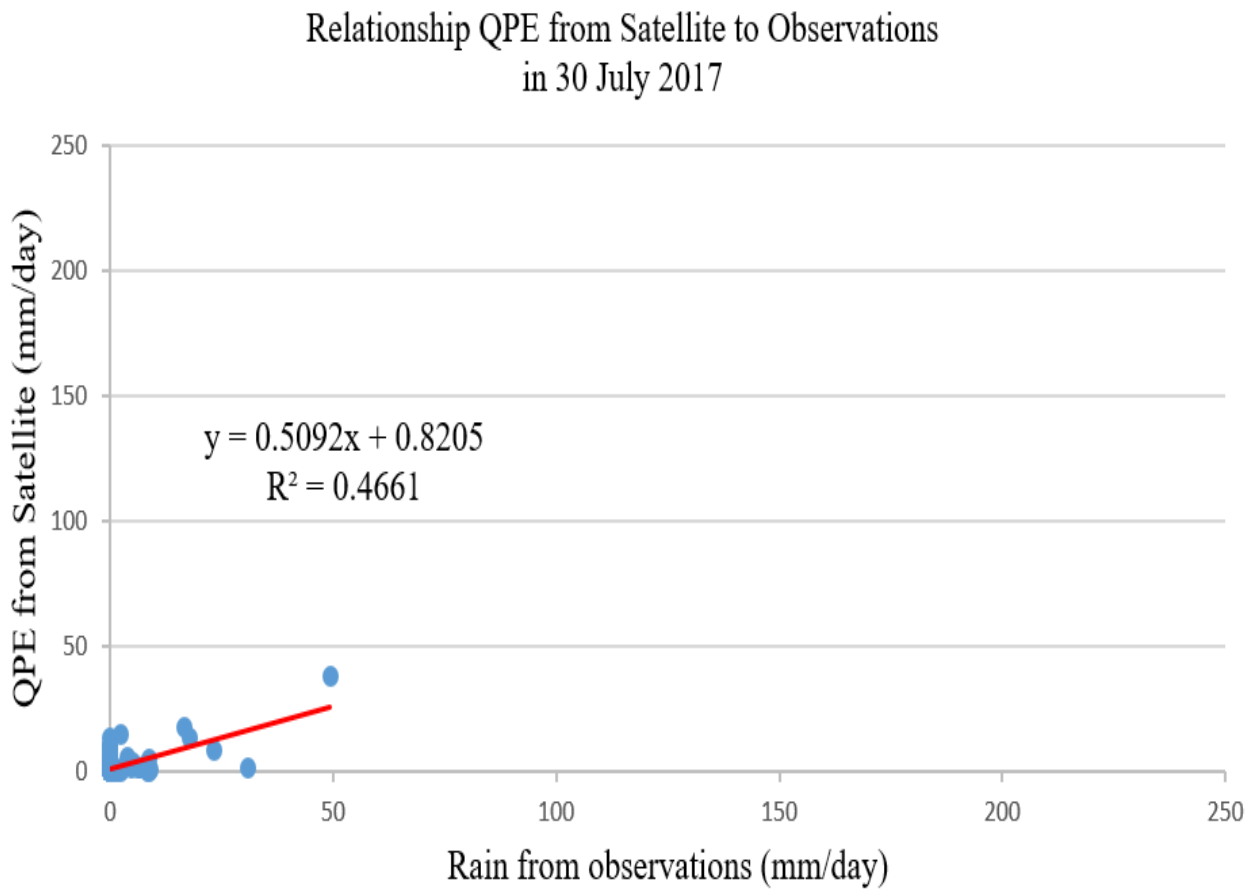


The relation rainfall distribution from QPE from satellite to observations.





The relation rainfall distribution from QPE from satellite to observations.



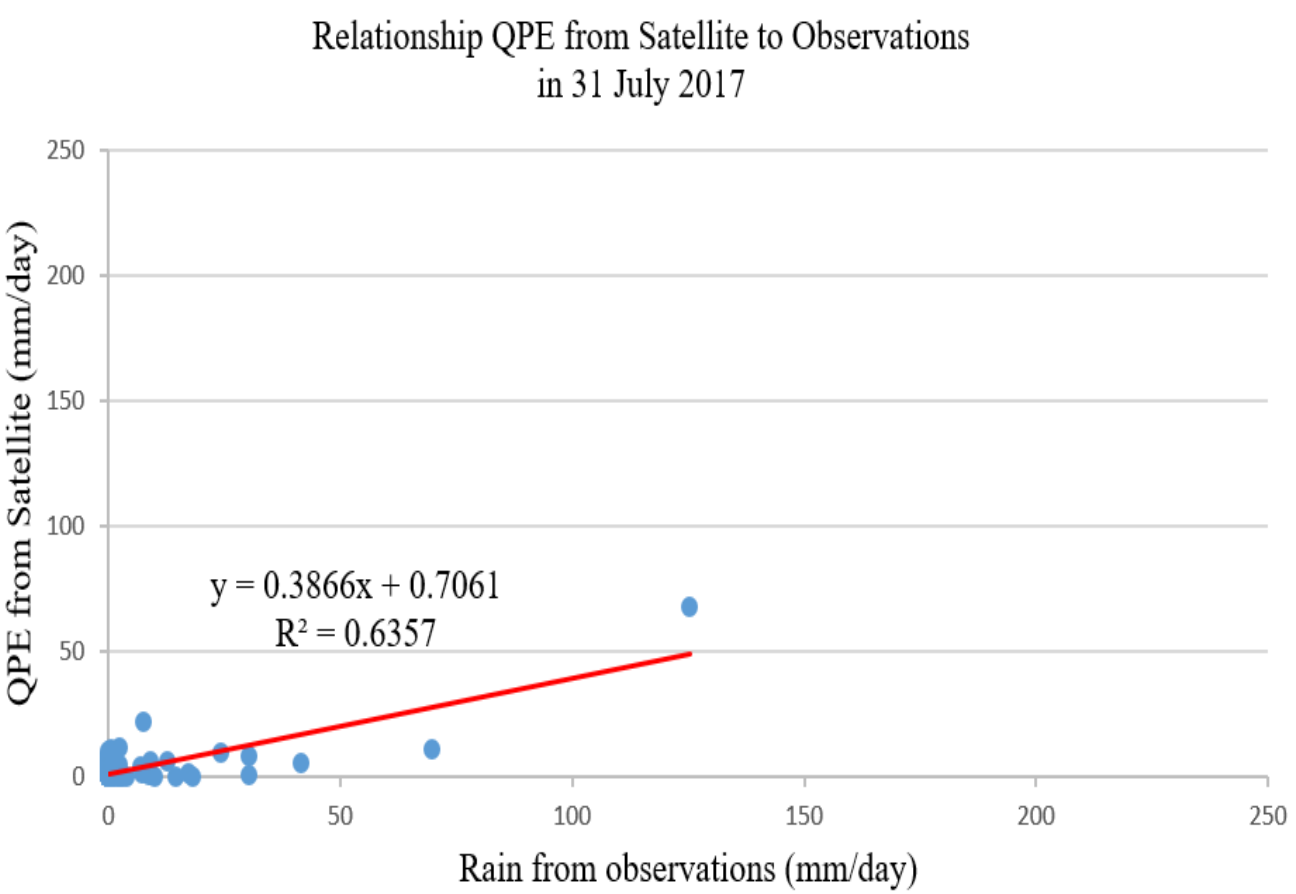


Table 1: Table 1: Statistic relationship distribution of QPE from Sat. to rainfall from Obs. during 26-31 July 2017.

Date	R^2	CC	MAE	RMSE
26 July 2017	0.8593	0.9271	8.9066	12.6878
27 July 2017	0.6196	0.7871	8.7655	17.1806
28 July 2017	0.7872	0.8872	7.0861	11.7362
29 July 2017	0.6619	0.8136	3.7098	7.1156
30 July 2017	0.4683	0.6844	2.0401	4.5587
31 July 2017	0.6368	0.7980	3.6164	9.7508

Table 2: Statistic verification of detection during 26-31 July 2017

Date	Hit	False alarm	Miss	Correct Rejection	POD	FAR	POFD	TS
26 July 2017	104	0	9	9	0.9981	0.0796	0.5000	0.9203
27 July 2017	71	22	10	19	0.7634	0.1234	0.3448	0.6893
28 July 2017	68	5	28	21	0.9315	0.2917	0.5713	0.6733
29 July 2017	47	13	28	34	0.7833	0.3733	0.4516	0.5341
30 July 2017	31	11	30	50	0.7381	0.4180	0.3750	0.4306
31 July 2017	21	11	18	72	0.6563	0.4615	0.2001	0.4202

The study of QPE from the satellite meteorology with the relationship between the temperature of the cloud and rainfall in the area by the geo-satellite in infrared (IR) band of FY-2E (Kamol P.N. Sakolnakhon and Sarintip, T., 2014) and Himawari as same as the equation, QPE results from Himawari satellite showed a similar products from FY-2E.

Impact from Tropical Depression “SONCA” flood occurred

27 July 2017, 17.40p.m. in front of Central, K

Impact from Tropical Depression “SONCA” flood occurred

27 July 2017, 17.40p.m. in front of Central, Khon Khean

Impact from Tropical Depression “SONCA” flood occurred

27 July 2017, 17.40p.m. in front of Central, Khon Khean

5. *Conclusion*

In order to the original equation modify the brightness temperature according to the convective equilibrium level temperature prior to computing rainfall rate, the estimation rainfall from satellite can compute from the relationship between rainfall rate and temperature of cloud in infrared band (IR) in the each grid point, bias-correction and also was applied Kriging method to interpolate.

5. *Conclusion*

Comparison between QPE from satellite to observation in each day, it can be seen that QPE is distribution light rain, moderate rain, heavy rain and also very heavy rain similar observations, the regression statistic output of linear and QPE function, it showed that linear function provide high R^2, low MAE and RMSE. The statistic verification POD and TS quit approach to 1.0, and also FAR and POFD quit approach to 0.0 that indicated the algorithm R-T relationship can calculate QPE in the area.

Future Work

- IR band of Himawari 8/9 satellite composed of 4 bands and also which was selected the best one to simulation rainfall by the equation R-T.

- Bias-correction so many method to use that was selected one method to compute.

- Intergrade method is many methods which was selected one method to compute.

Acknowledgements

The author especially indebted to **Boonlert V., JMA team, JAXA team** who have been supportive technique and also all comments in this paper to successfully done.

Cảm ơn bạn

Thank You