MRCFFG Rainfall Estimate

Hydrologic Research Center
San Diego, California

Present: Eylon Shamir Eshamir@hrcwater.org

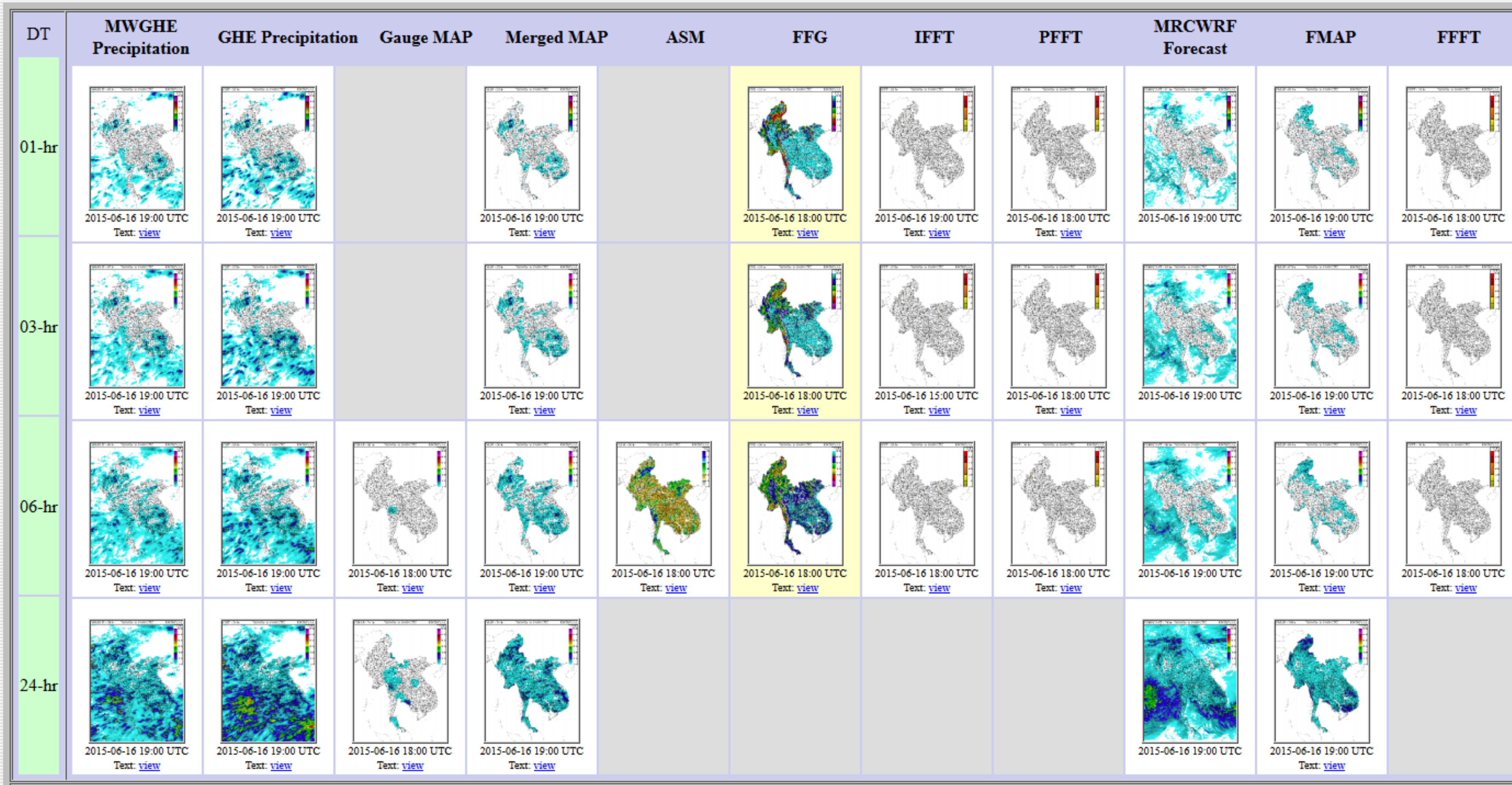
Initial Training Workshop & First Steering Committee Meeting (SCM 1)

29 November – 1 December, 2016

Phnom Penh, Cambodia

Rainfall Estimate Products

https://mrcffg.hrc-lab.org/MRCFFG/



DT	MWGHE Precipitation	GHE Precipitation	Gauge MAP	Merged MAP	ASM	FFG	IFFT	PFFT	MRCWRF Forecast	FMAP	FFFT
01-hr	2015-06-16 19:00 UTC Text: view	2015-06-16 19:00 UTC Text: view		2015-06-16 19:00 UTC Text: view		2015-06-16 18:00 UTC Text: view	2015-06-16 19:00 UTC Text: view	2015-06-16 18:00 UTC Text: view	2015-06-16 19:00 UTC	2015-06-16 19:00 UTC Text: view	2015-06-16 18:00 UTC Text: view
03-hr	2015-06-16 19:00 UTC Text: view	2015-06-16 19:00 UTC Text: view		2015-06-16 19:00 UTC Text: view		2015-06-16 18:00 UTC Text: view	2015-06-16 15:00 UTC Text: view	2015-06-16 18:00 UTC Text: view	2015-06-16 19:00 UTC	2015-06-16 19:00 UTC Text: view	2015-06-16 18:00 UTC Text: view
06-hr	2015-06-16 19:00 UTC Text: view	2015-06-16 19:00 UTC Text: view	2015-06-16 18:00 UTC Text: view	2015-06-16 19:00 UTC Text: view	2015-06-16 18:00 UTC Text: view	2015-06-16 18:00 UTC Text: view	2015-06-16 18:00 UTC Text: view	2015-06-16 18:00 UTC Text: view	2015-06-16 19:00 UTC	2015-06-16 19:00 UTC Text: view	2015-06-16 18:00 UTC Text: view
24-hr	2015-06-16 19:00 UTC Text: view	2015-06-16 19:00 UTC Text: view	2015-06-16 18:00 UTC Text: view	2015-06-16 19:00 UTC Text: view					2015-06-16 19:00 UTC	2015-06-16 19:00 UTC Text: view	

Composite Product: text, CSV, CSVT

SFTP data transfer (requires SFTP Client): EXPORTS/REGIONAL/2015/06/16

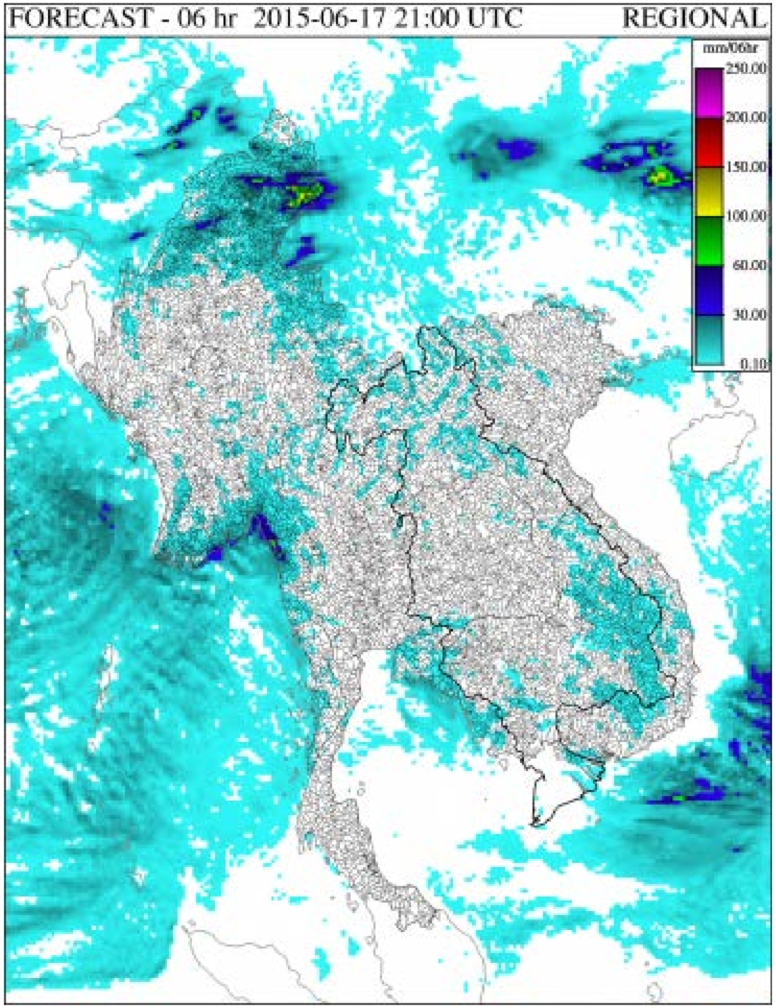
Surfmet Gauge Observations at 2015-06-16 18:00 UTC

Station Identifier	Station Name	Accumulated Precipitation (mm/06hr)	Average Temperature (C)	Region	Latitude	Longitude	Elevation	Enable Precipitation Flag	Enable Temperature Flag
48300	MAE HONG SON	No Report	27.10	THAILAND	19.3	97.83333333	269	Enabled	Enabled
48302	DOI ANG KHANG	Reported Missing	19.65	THAILAND	19.91666667	99.03333333	1530	Enabled	Enabled
48303	CHIANG RAI	No Report	26.30	THAILAND	19.96666667	99.88333333	395	Enabled	Enabled
48304	CHAING RAI AGROMET	No Report	25.10	THAILAND	19.86666667	99.76666667	401	Enabled	Enabled
48307	TUNG CHANG	Reported Missing	24.75	THAILAND	19.41666667	100.8833333	335	Enabled	Enabled
48310	PHAYAO	No Report	26.20	THAILAND	19.13333333	99.9	399	Enabled	Enabled
48315	THA WANG PHA	Reported Missing	25.85	THAILAND	19.11666667	100.8	236	Enabled	Enabled

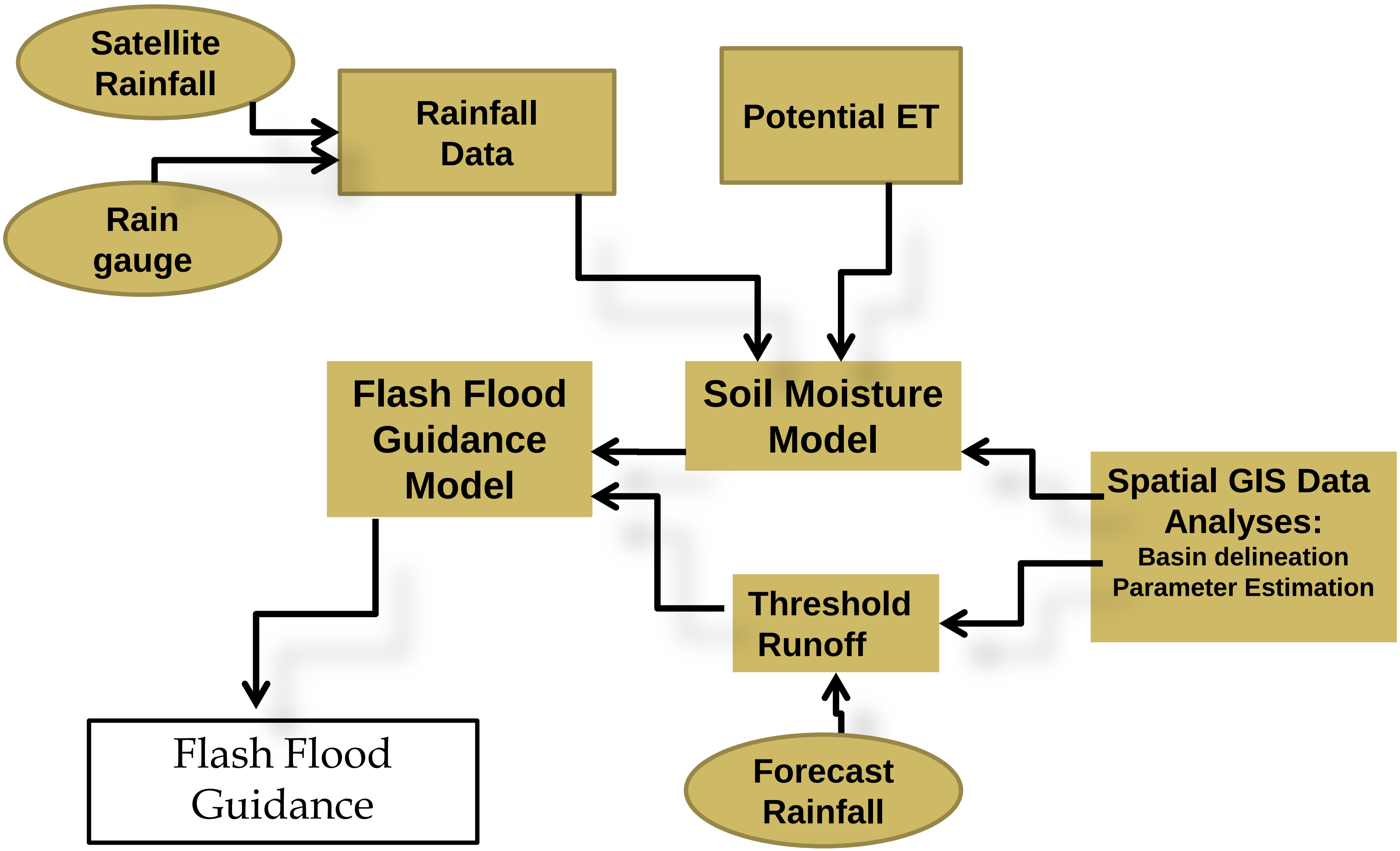
Forecast Model [WRF]

NCAR WRF Core 3.2.
Large Domain: 4-31^{o}N and 89-112^{o}E (27 x 23 degrees). The implemented model configuration was selected based on required processing time.

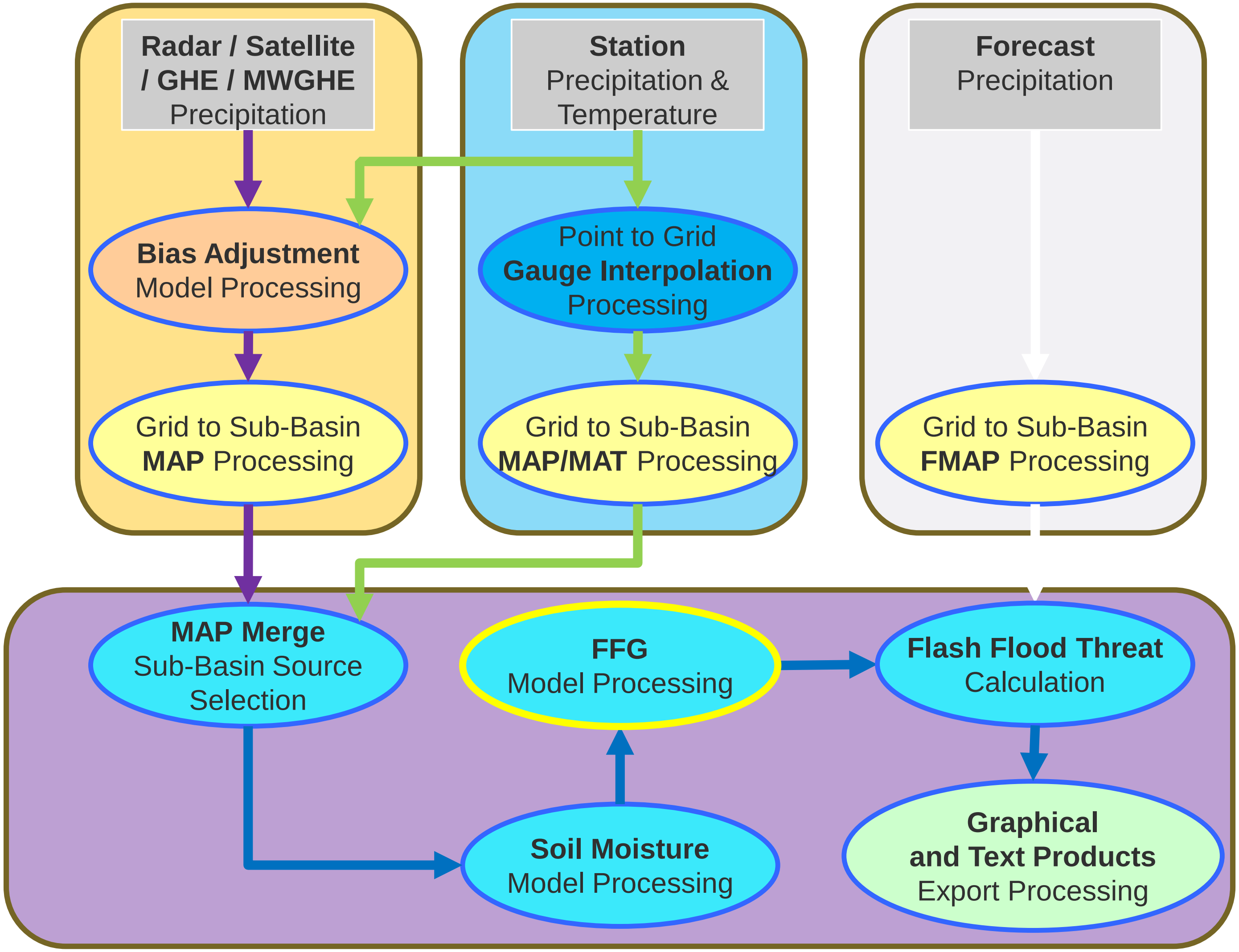
- Resolution of 11km,
- Initial and boundary conditions from the Global Forecast System (GFS) NCEP at a 0.5 degree spatial resolution.
- Model run twice daily at 00UTC and 12UTC, with a 48-hour forecast lead time and hourly resolution.



The Components of the Flash Flood Guidance System

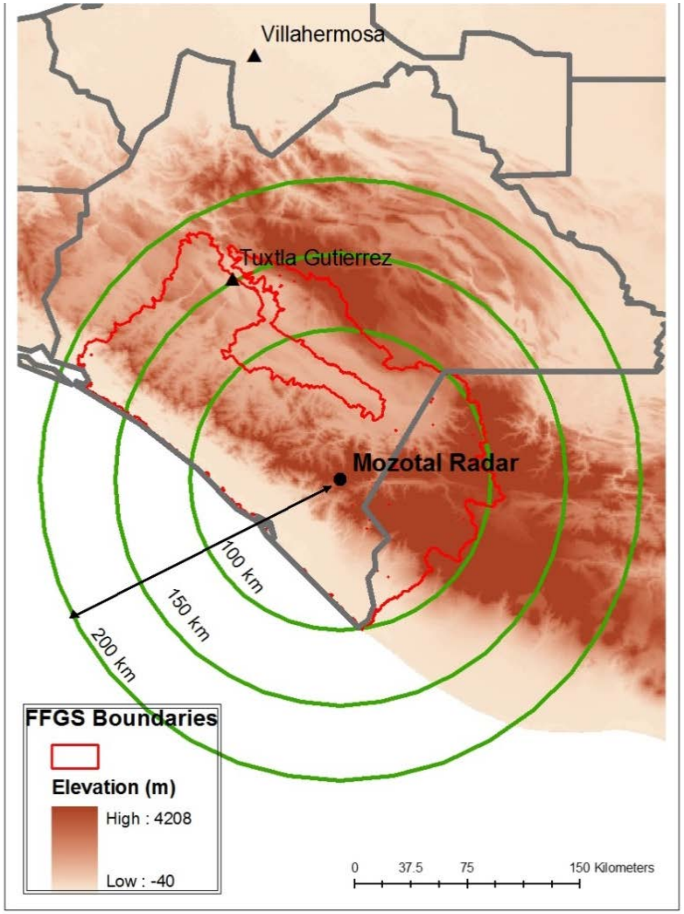


FFGS Model Processing Overview

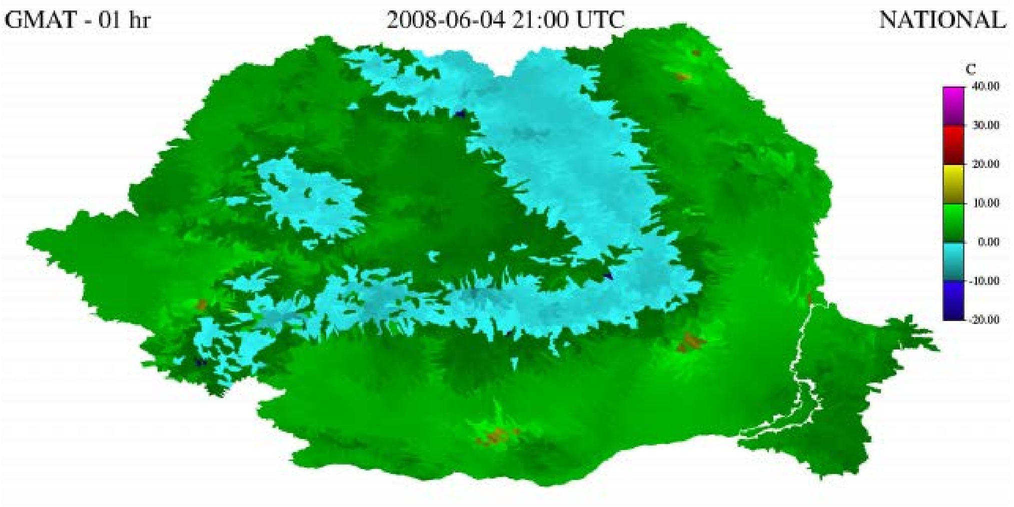


Radar Based FFG Systems

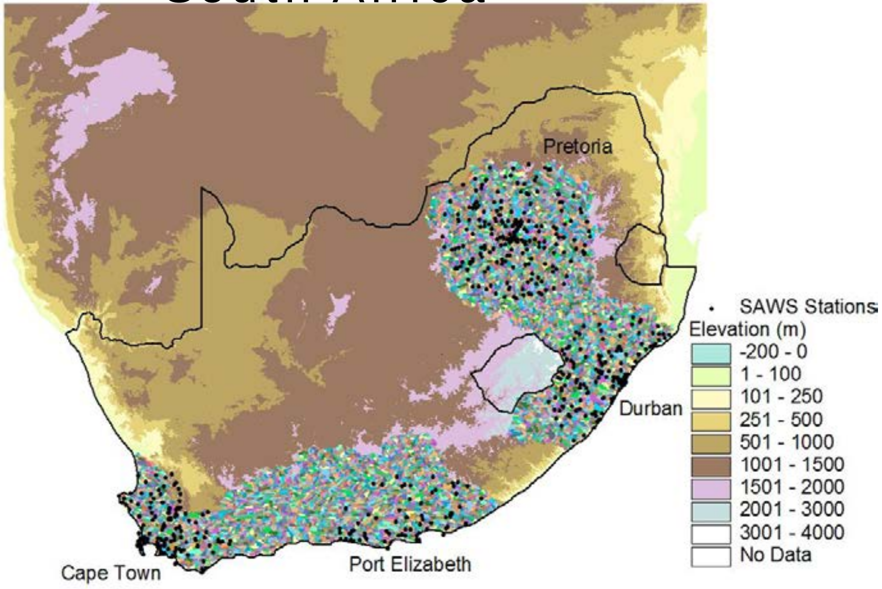
Mexico



Romania



South Africa

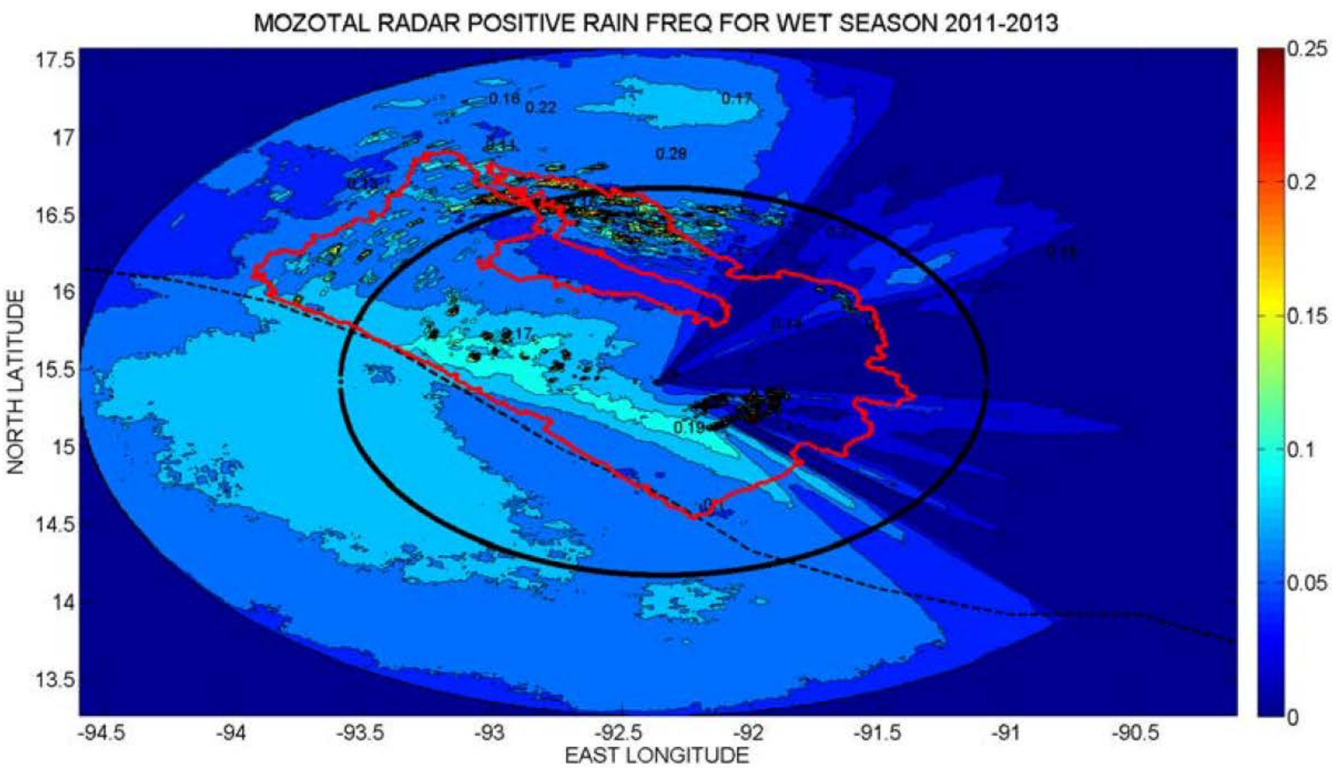


Analysis for identification of persistent errors by comparing the frequency of rainy hours in the radar

Persistent Error Sources in Estimates of Precipitation based on Radar Data

- Beam Blockage (Mountains, forests, towers, etc.,)
- Anomalous Propagation (AP) (Inversions and vapor gradient conditions)
- Non-Precipitation Echoes (interference from objects other than raindrops)
- Bright Banding (melting of falling snow and ice crystals)
- Hail Contamination (Abnormally high reflectivity)
- Range Degradation (under sampling at far ranges, signal attenuation)
- Improper Z-R Relationships
- Signal attenuation for C-band radars
- Unaccounted precipitation processes below the CAPPI level for high-altitude radars
- Electronic Calibration
- Algorithm Errors

Frequency of Positive Rainfall Events



[redacted] Positive rainfall frequencies for radar-umbrella pixels of Mozotal radar (colors) and associated values of on-site gauge stations with near complete records.[redacted]

Histogram of radar rain detection frequency

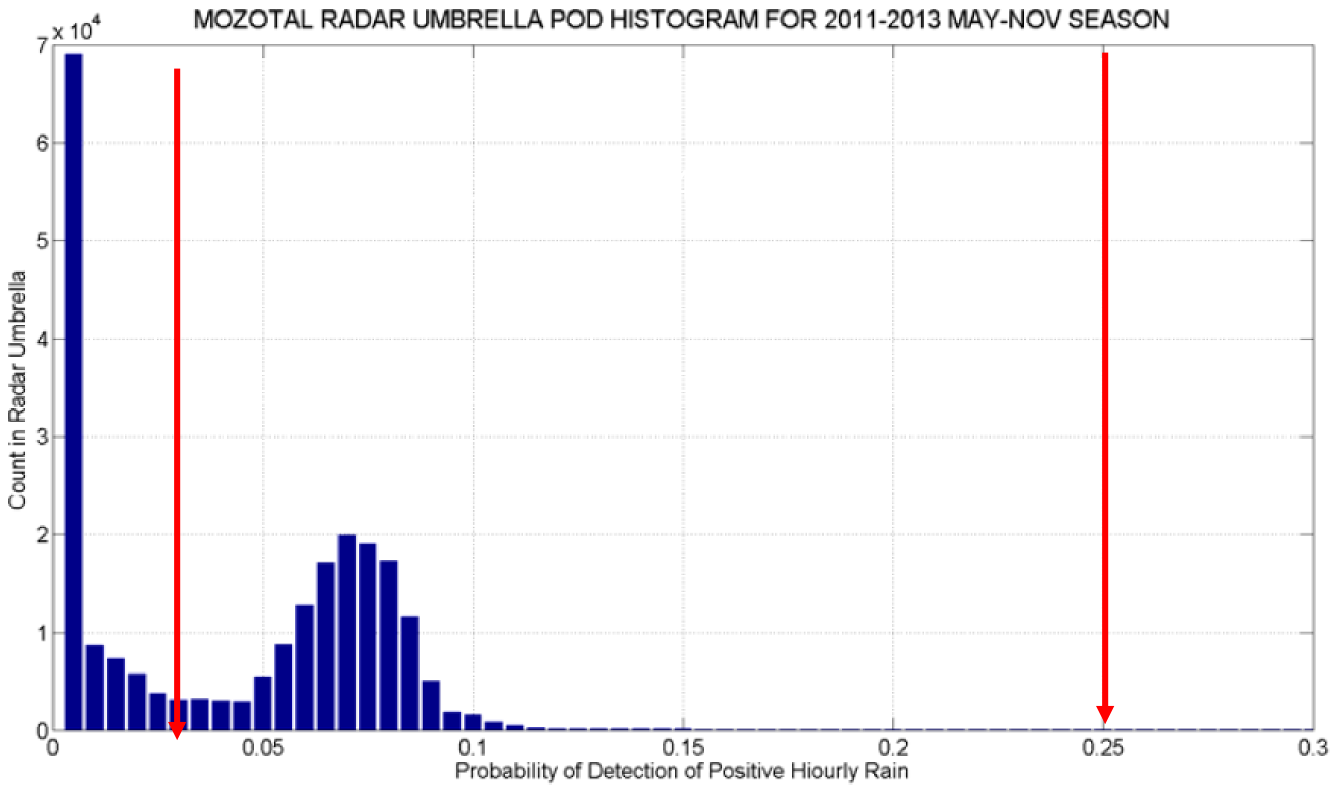


Figure 8: Histogram of positive rainfall pixel frequencies within the Mozotal radar umbrella for the period 2011-2013 (May – November).

Reasons for Satellite Precipitation Bias

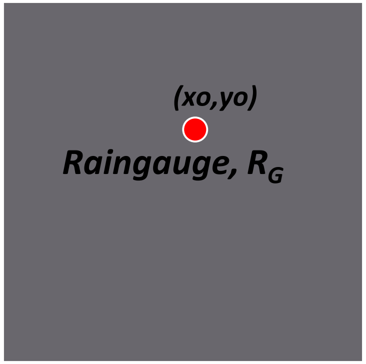
Bias may exist in the remotely sensed precipitation estimates relative to gauges. This should be removed before inputting to hydrologic models.

- Vastly different scales of satellite pixel and rain gauge area
- Orography organizes surface rainfall according to prevailing winds
- Satellite estimates do not directly measure rainfall at surface
- There may be significant misregistration errors in satellite data

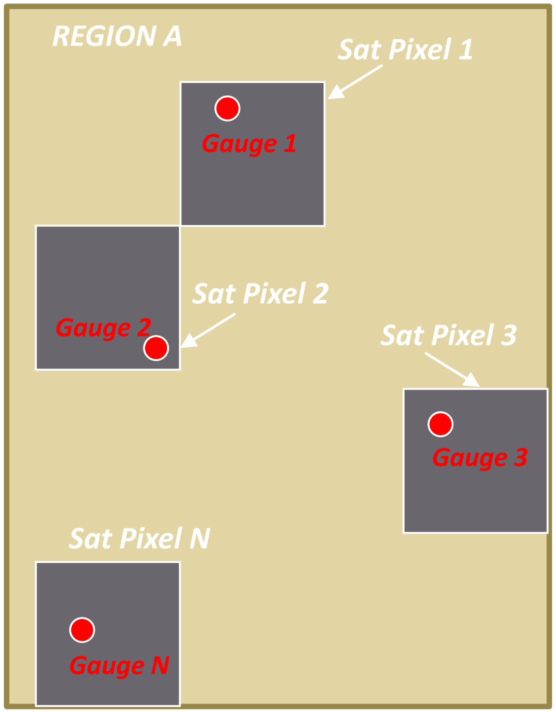
Operational Quality Control and Enhancement of Radar Data to Support Regional Flash Flood Warning Systems

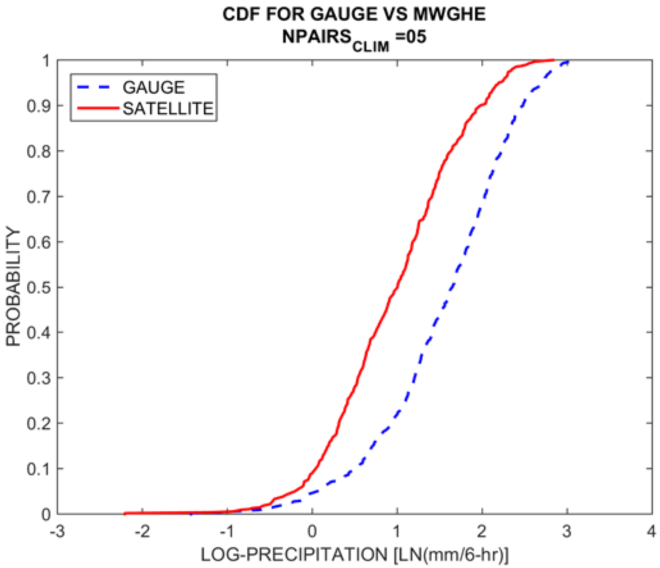
Theresa M. Modrick, Ph.D.[1]; Konstantine P. Georgakakos, Sc.D., M.ASCE[2]; Eylon Shamir, Ph.D.[3]; and Cristopher R. Spencer[4]

Satellite Pixel, R_{SAT}



Climatological Bias Adjustment for Satellite Precipitation





Log Bias:

$$\beta_t = \ln\left\{\frac{\sum_{j=1}^{N_G} R_G(j,t)/NG}{\sum_{j=1}^{N_G} R_{SAT}(j,t)/NG}\right\}$$

Approach for both climatological and real-time bias.

Dynamic Bias Adjustment

$$\beta_t = \ell n \left[\frac{\sum_{j=1}^{N_g} R_g(t,j)}{\sum_{j=1}^{N_g} R_s(t,j)} \right]$$

$$\beta_{t+1} = \beta_t + w_{t+1}$$

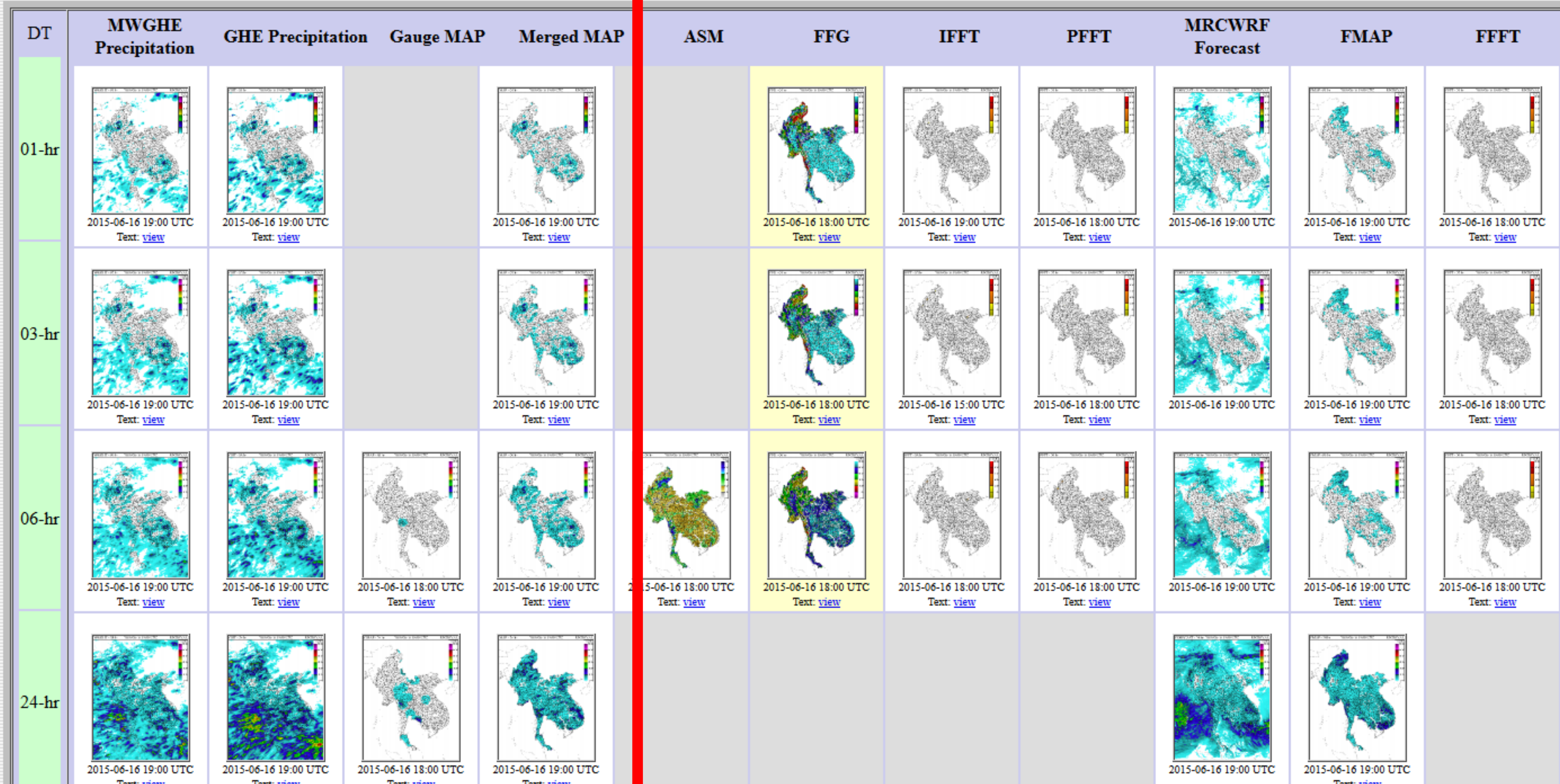
$$z_{t+1} = \beta_{t+1} + v_{t+1}$$

Kalman Filter
Stochastic Approximations

- N pairs of consecutive values
- At least 20% raingauges with rain
- Conditional Mean > Threshold (mm/h) (satellite and gauge)

Bias (B)

Rainfall Estimate Products



Composite Product: text, CSV, CSVT | SFTP data transfer (requires SFTP Client): EXPORTS/REGIONAL/2015/06/16

Surfmet Gauge Observations at 2015-06-16 18:00 UTC

Station Identifier	Station Name	Accumulated Precipitation (mm/06hr)	Average Temperature (C)	Region	Latitude	Longitude	Elevation	Enable Precipitation Flag	Enable Temperature Flag
48300	MAE HONG SON	No Report	27.10	THAILAND	19.3	97.83333333	269	Enabled	Enabled
48302	DOI ANG KHANG	Reported Missing	19.65	THAILAND	19.91666667	99.03333333	1530	Enabled	Enabled
48303	CHIANG RAI	No Report	26.30	THAILAND	19.96666667	99.88333333	395	Enabled	Enabled
48304	CHAING RAI AGROMET	No Report	25.10	THAILAND	19.86666667	99.76666667	401	Enabled	Enabled
48307	TUNG CHANG	Reported Missing	24.75	THAILAND	19.41666667	100.8833333	335	Enabled	Enabled
48310	PHAYAO	No Report	26.20	THAILAND	19.13333333	99.9	399	Enabled	Enabled
48315	THA WANG PHA	Reported Missing	25.85	THAILAND	19.11666667	100.8	236	Enabled	Enabled

Multi-Spectral Satellite Rainfall

GHE

IR – Based
30-min latency in operations
Three snapshots per hour
4x4 - km
Based on measurements of top
Cloud brightness temperature

CMORPH

MW – Based
18-26 hour latency in operations
8x8 km
Based on measurements of
Microwave scattering from raindrops
Different algorithms over sea and land
Masked for areas with snow

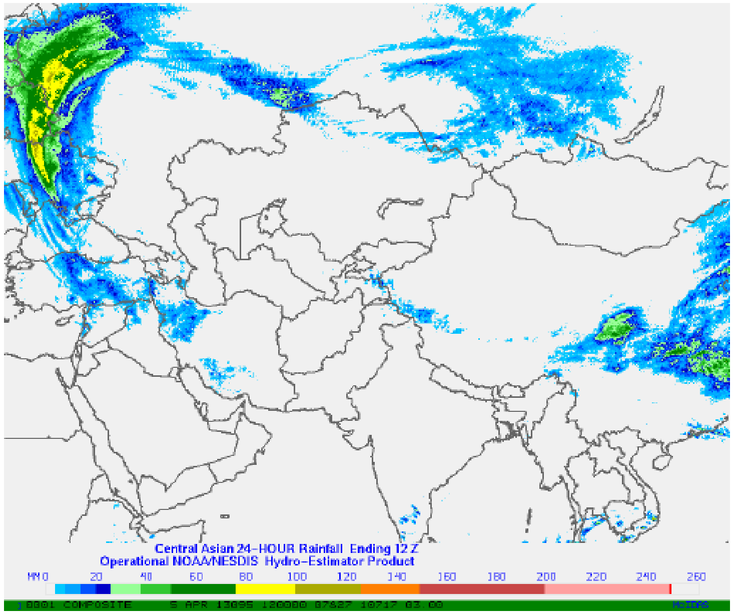
New development aims to combine IR-based HE rainfall with MW-based CMORPH rainfall

Satellite Precipitation Estimates

Satellite Precipitation estimates provide near-global coverage, and critical information in regions with sparse coverage by traditional gauge or radar networks.

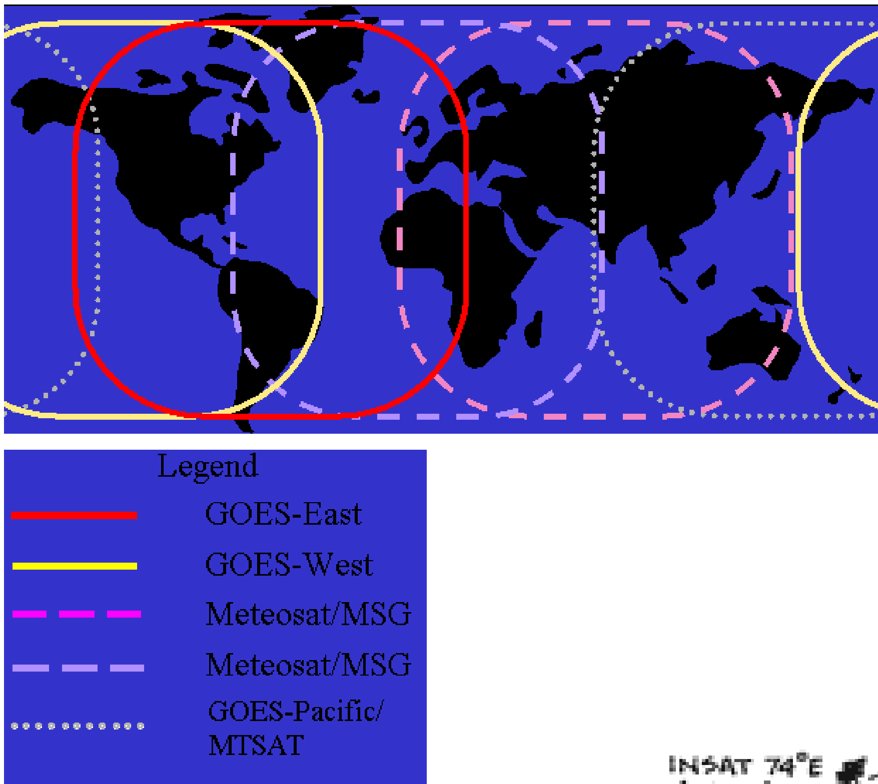
These can be used in hydrologic applications.

- *However, these are INDIRECT* measures of rainfall rate
- Bias may exists relative to ground observations
- Example of NOAA/NESDIS Hydro-Estimator
  - Infrared (IR) based estimate of rainfall rate
  - research/development since late 1970s
  - *Operational* product, hourly precipitation estimates with latency < 1 hour.
- Other products more recently available
  - CPC CMORPH: microwave-based estimate of rainfall rate, IR estimate of wind



NOAA/NESDIS H-E
24 Hour Rain Accum

Hydro- Estimator National Environmental Satellite, Data, and Information Service (NESDIS) (NOAA)



- Real-time operational since August 2002
- Available globally (60N-60S)
- Hourly values for about 4 km.
- geo-stationary GOES satellites IR 10.7 micron.
-
- Data are produced at the full instrument resolution and are updated whenever new imagery becomes available, with a latency of less than 15 minutes.

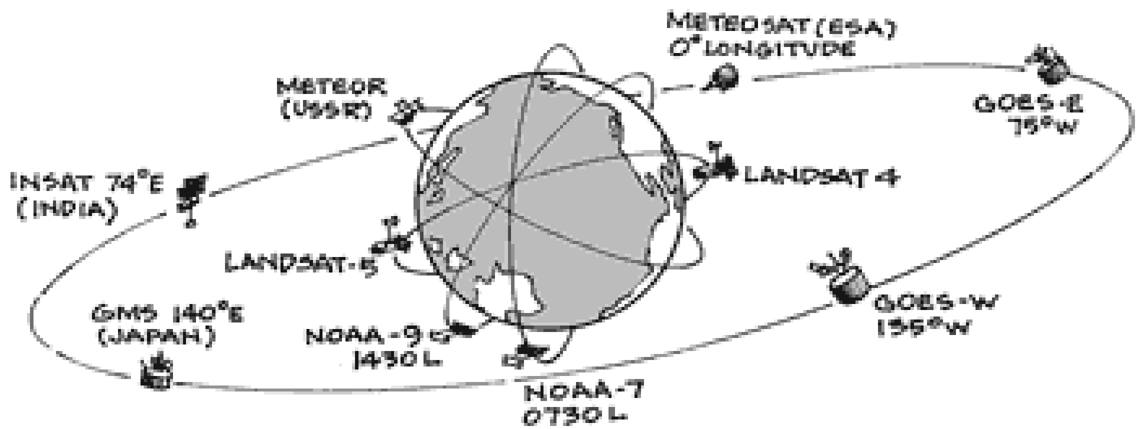
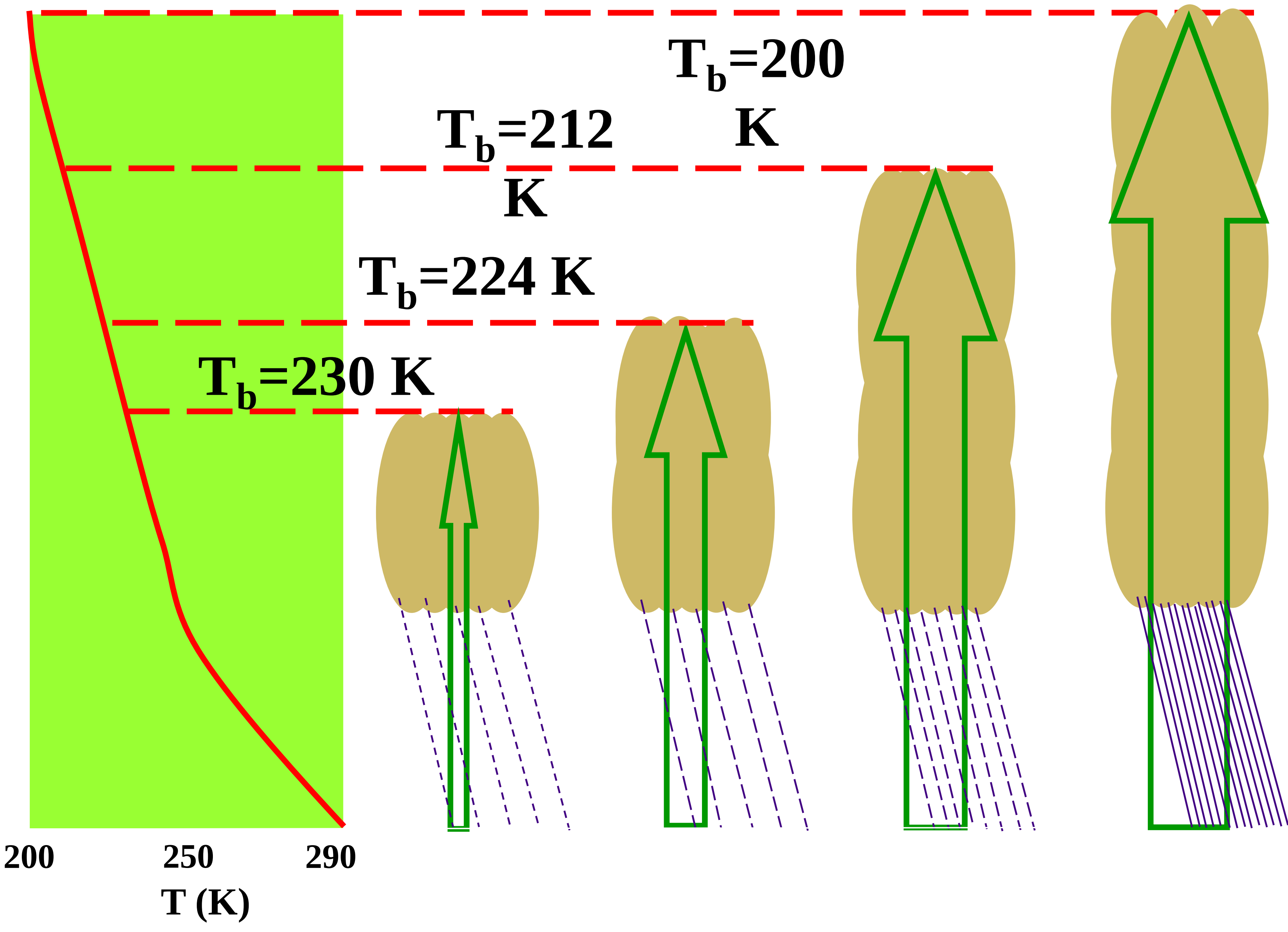
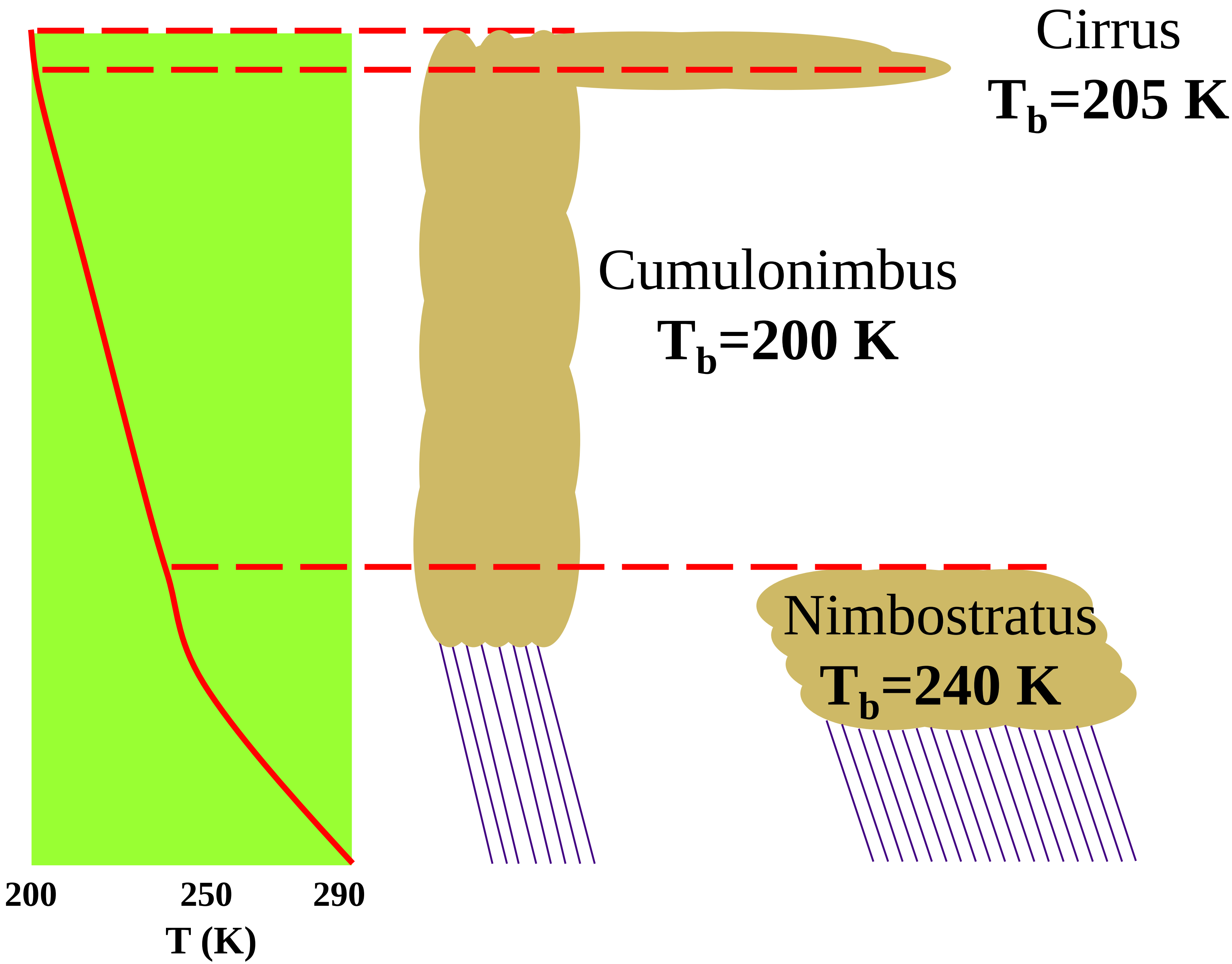


Illustration of the IR signal from different rainfall intensities



Exceptions to the Rule...



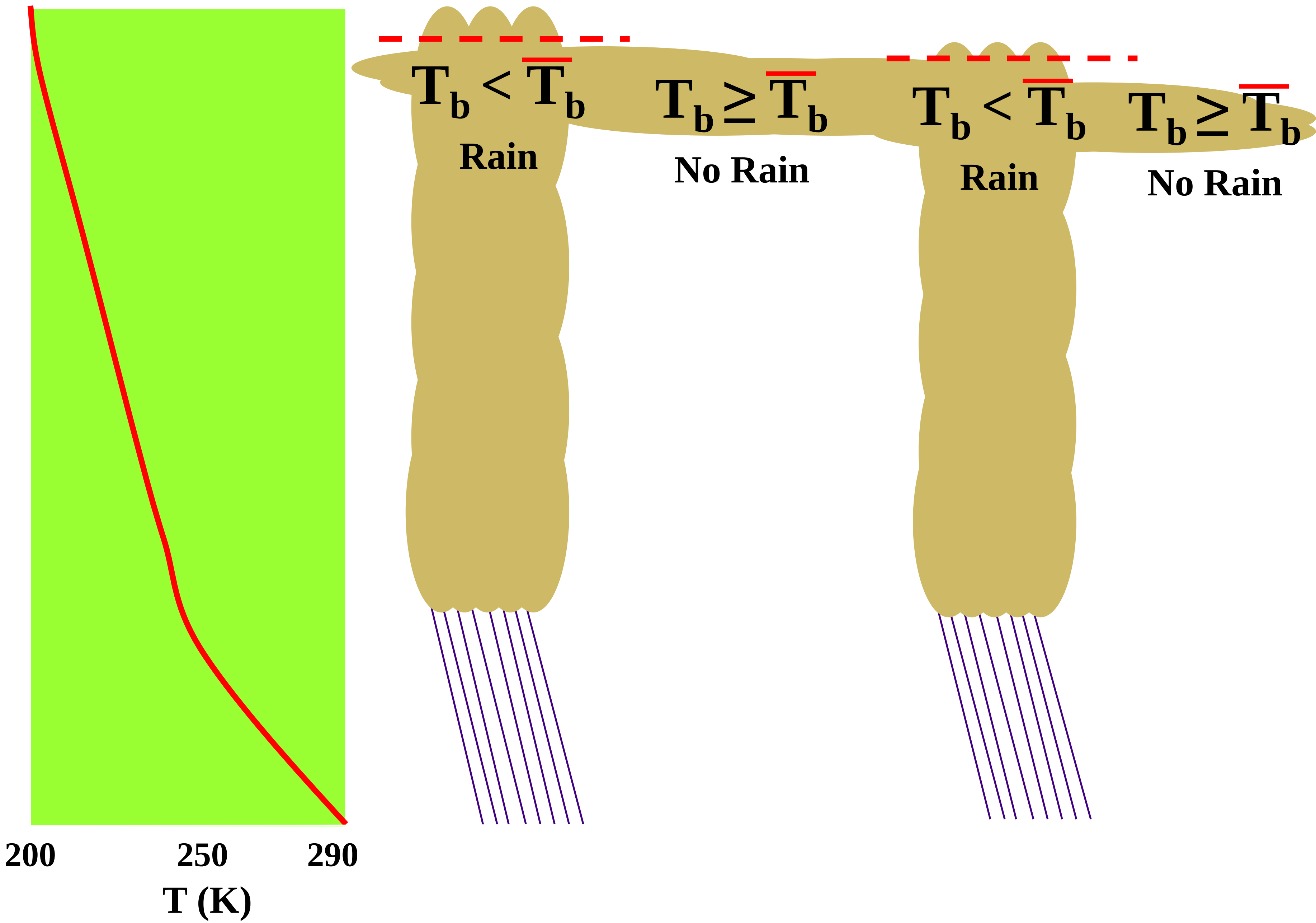
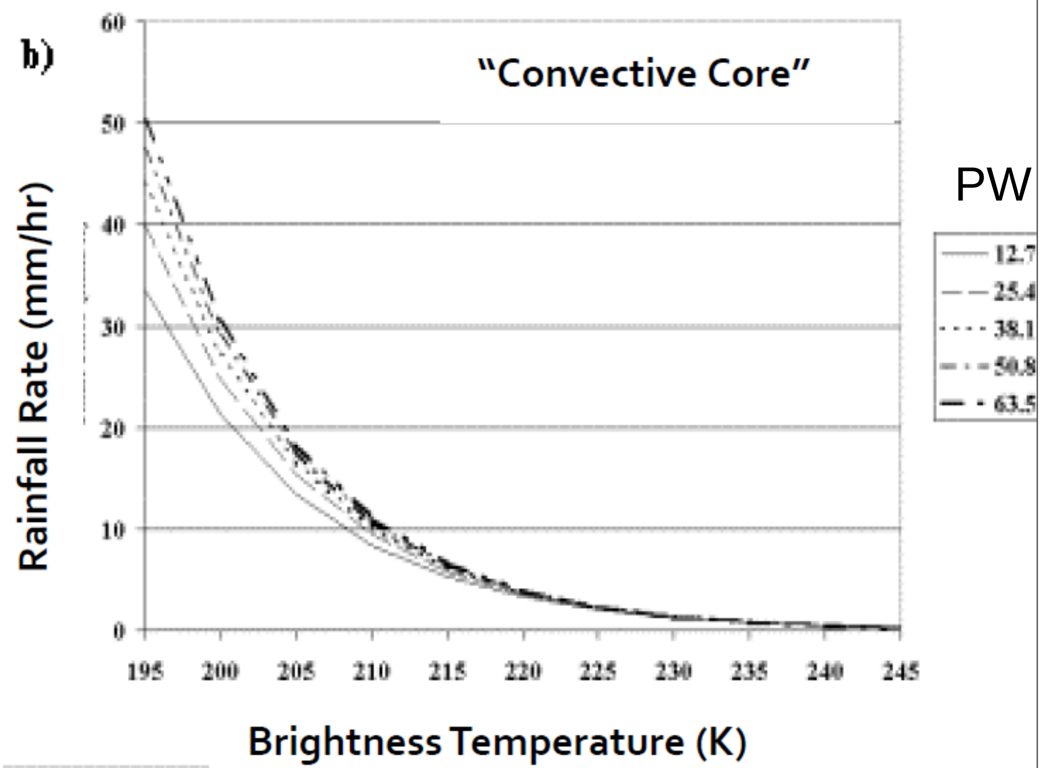


Illustration of the HE Rain-No Rain Differentiation

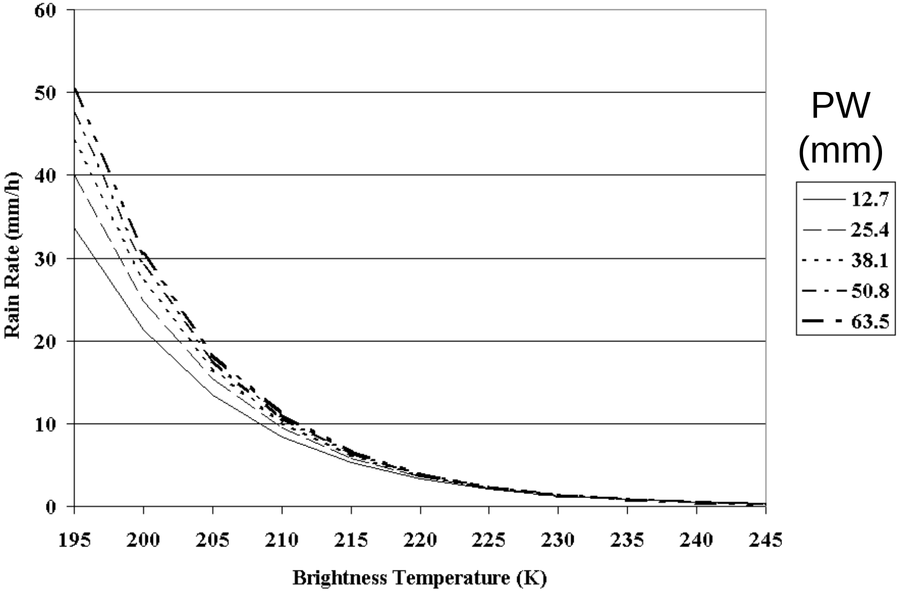
Global Hydro Estimator [GHE]

- NOAA/NESDIS Hydro-Estimator
  - Early work began in 1970's (Interactive Flash Flood Analyzer)
  - Auto-Estimator in late 1990's
  - Hydro-Estimator since 2002
- H-E relates rainfall rate to IR (infrared, 11 μm) brightness temperature
- H-E algorithm considers:
  - Atmospheric moisture
  - Orography
  - Convective Equilibrium
  - Surrounding temperature

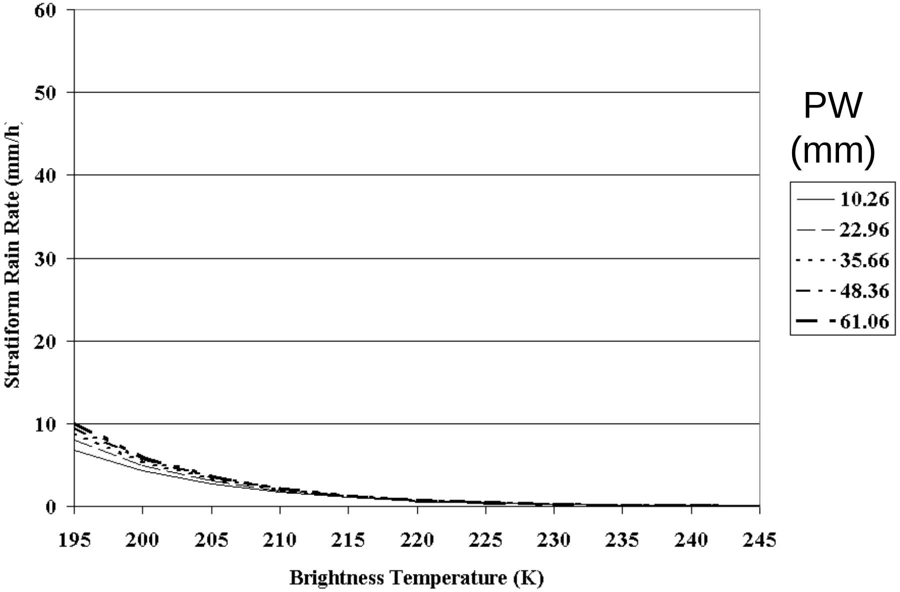


Rain rate as a function of brightness temperature and precipitable water in the Hydro-Estimator

“Convective Core” rainfall



“Non-core” rainfall



Hydro-Estimator (H-E)

- Basic assumption is that cloud-top brightness temperature is related to cloud height, which in turn is related to cloud thickness and to rainfall rate.

- Colder, brighter clouds are associated with heavier rain
- Warmer, less bright clouds are associated with light or no rain
- Reasonable assumption for convective clouds
- Poor assumption for
- - stratiform clouds (warm, but wet)
- - cirrus clouds (cold, but rain-free)

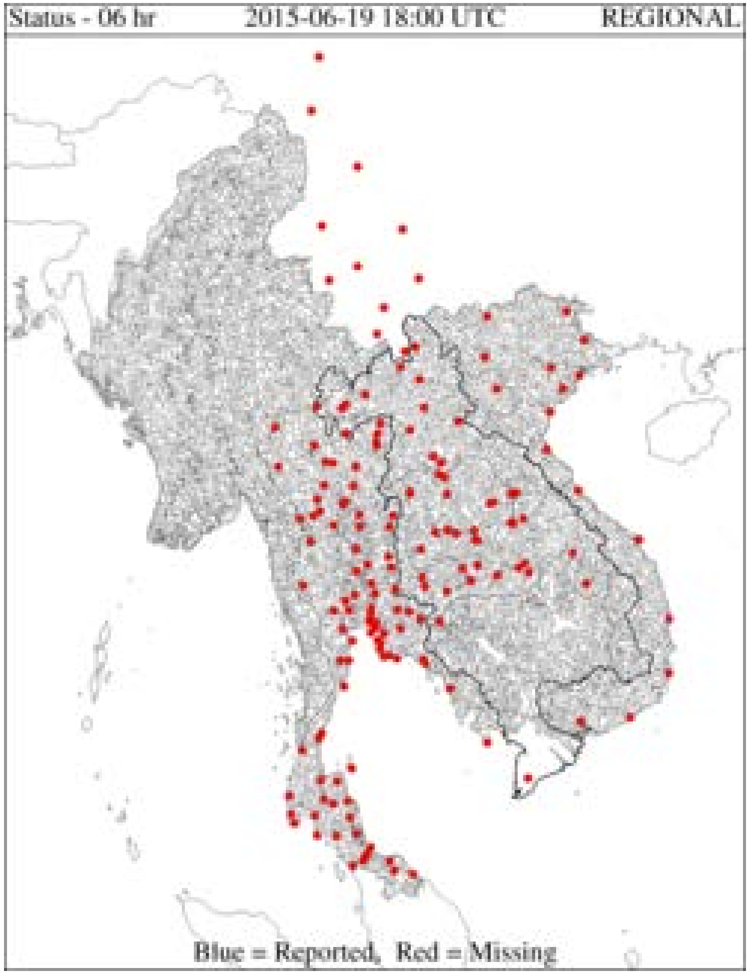
GHE algorithm corrections

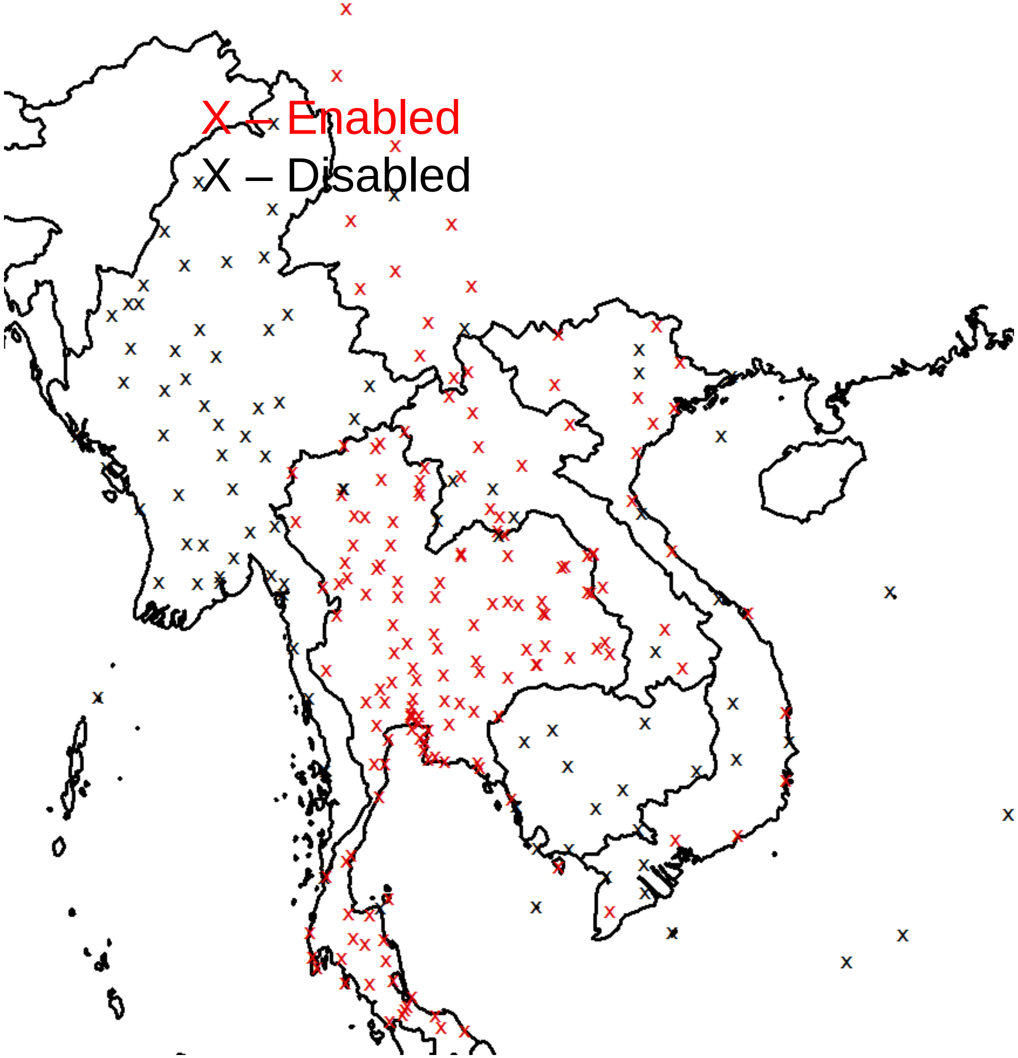
- H-E algorithm considers surrounding brightness temperature relative to the local average. i.e. colder (warmer) than average pixel is assigned active rain area (inactive cold cloud). This method was proven effective in portraying the rain spatial organization

- Eta (WRF) model Variables [operational Numerical Weather Prediction (NWP) mode]l
  - precipitable water (PW) to enhance (reduce) rain rates in high (low) PW areas;
  - relative humidity to reduce rain rates low-RH areas;
  - convective equilibrium level temperature to enhance rain rates in regions with values greater than 213 K;
  - 850-hPa winds interface with digital topography to correct for rain rates due to upslope and downslope regions.

- **Reference: Vicente et al. (1998, 2002).**

GTS Surface Met Gauges

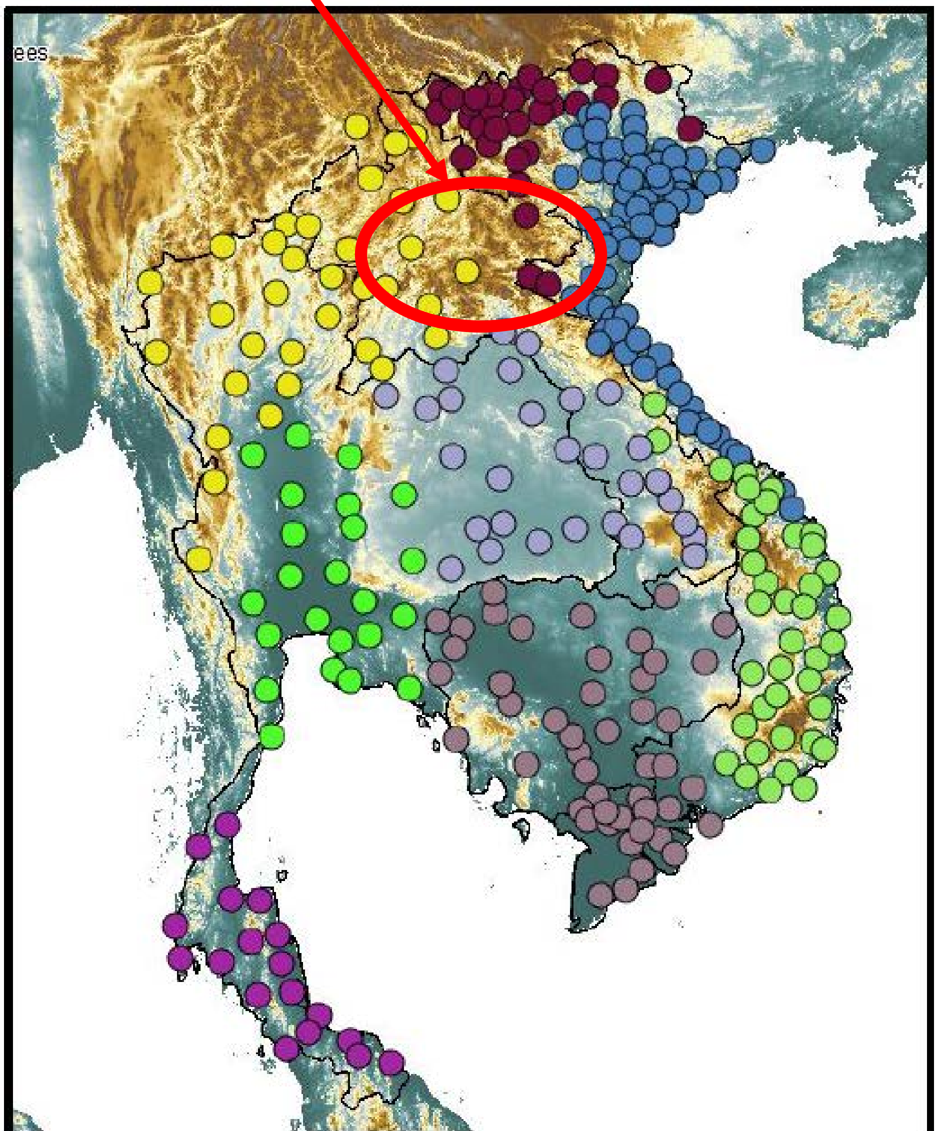




Note: not all enabled gauges are reporting

Climatological Bias Adjustment
8 –regions

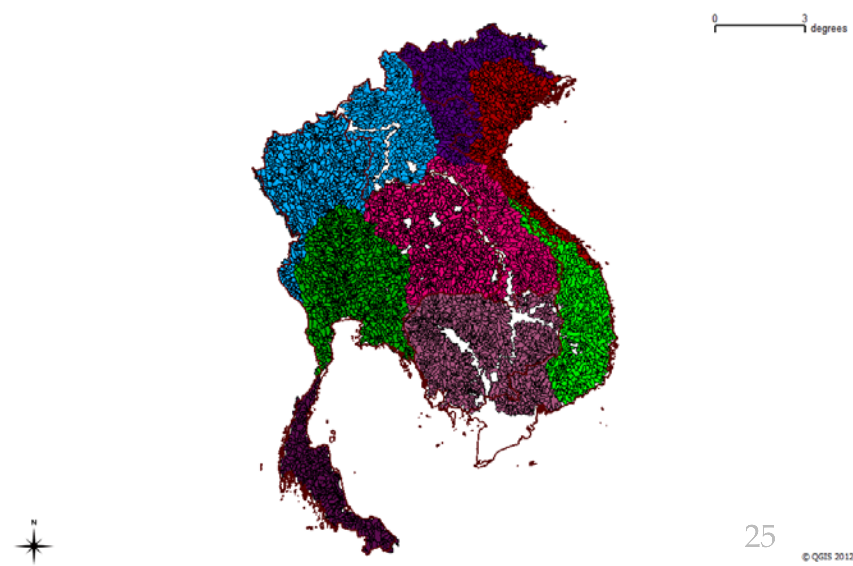
Few Gauges in high elevations



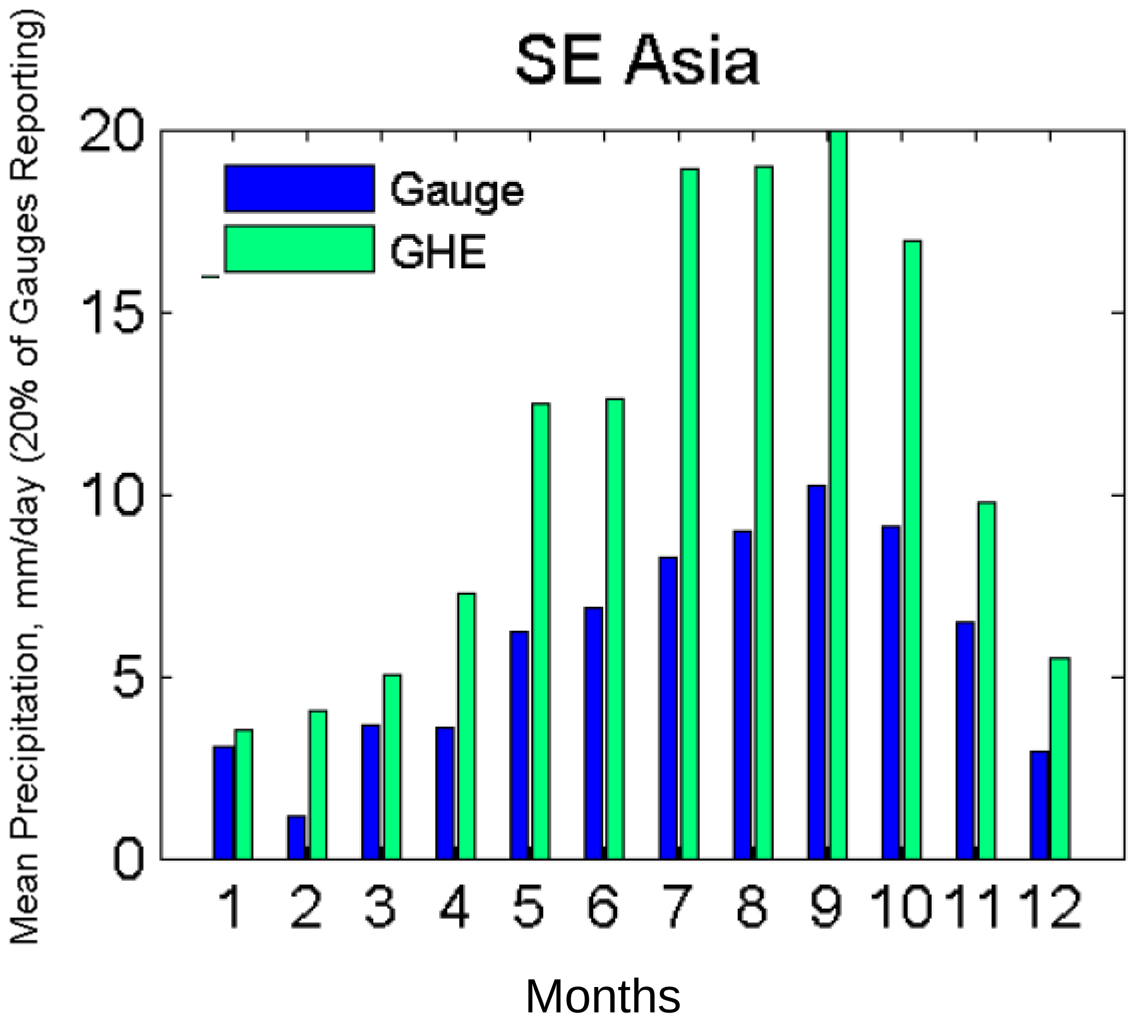
Georgakakos and Tospornsampan (2009) the first bias adjustment analysis

May-September 2009

395 - Daily Gauges
133 – MRC
146 - Vietnam (NCHMF)
116 –Thailand (TMD)

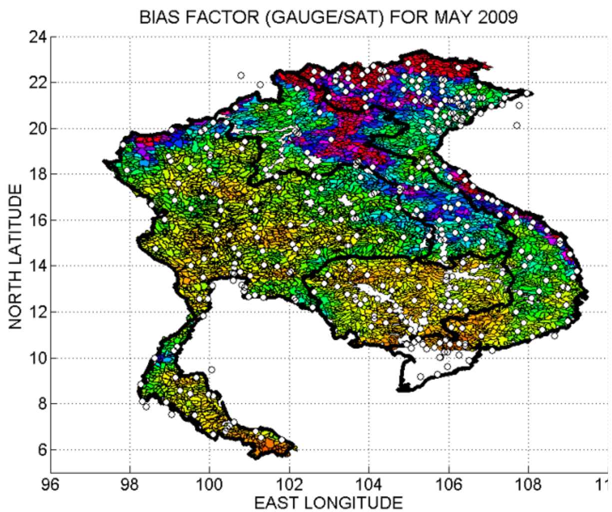


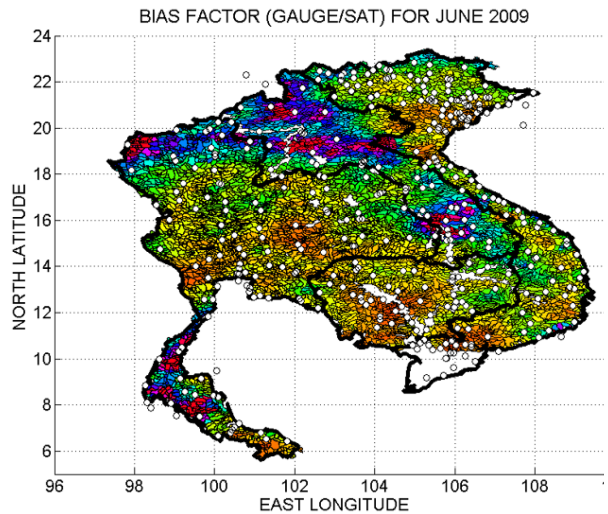
GHE-Gauges

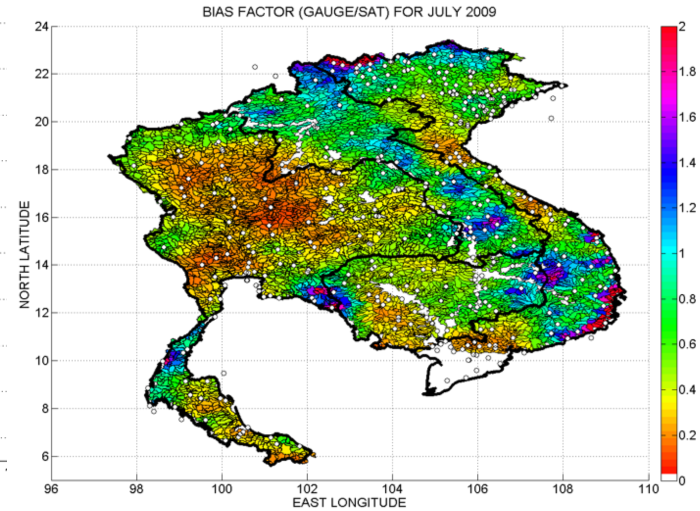


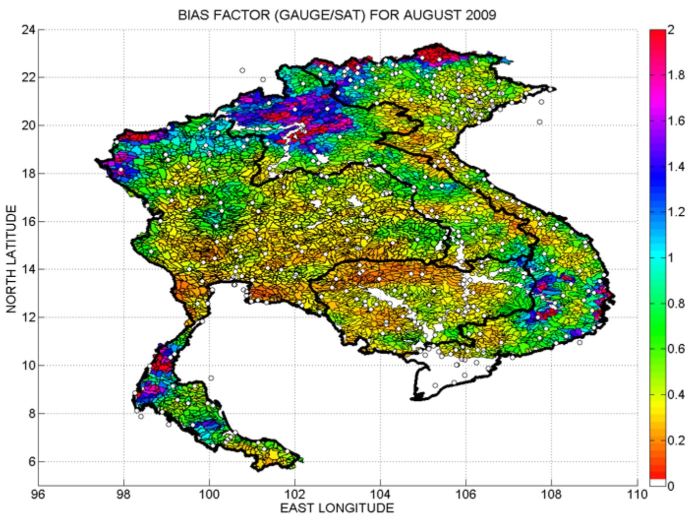
SE Asia
Gauge
GHE
20
15
10
5
0
1
2
3
4
5
6
7
8
9
10
11
12
Mean Precipitation, mm/day (20% of Gauges Reporting)
Months

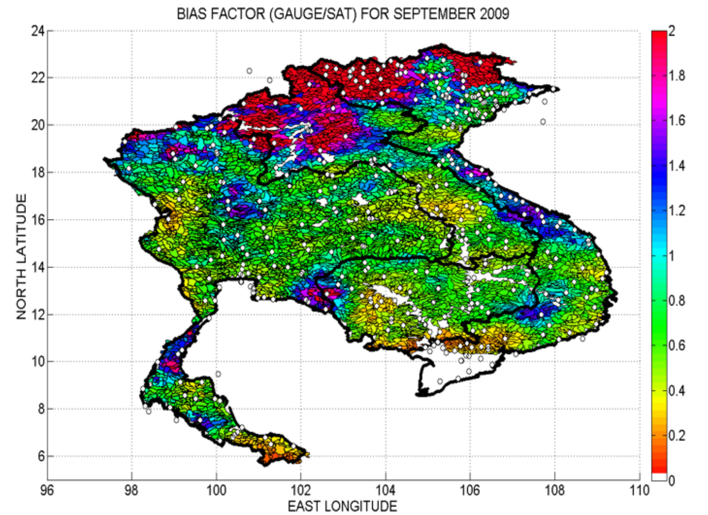
Monthly Climatological Factors





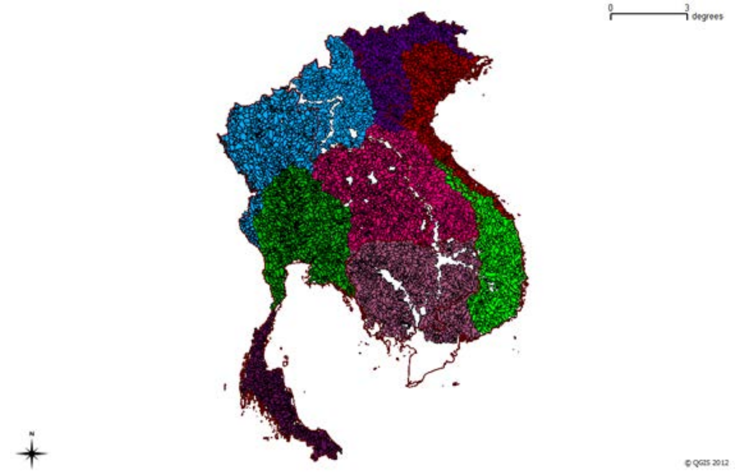




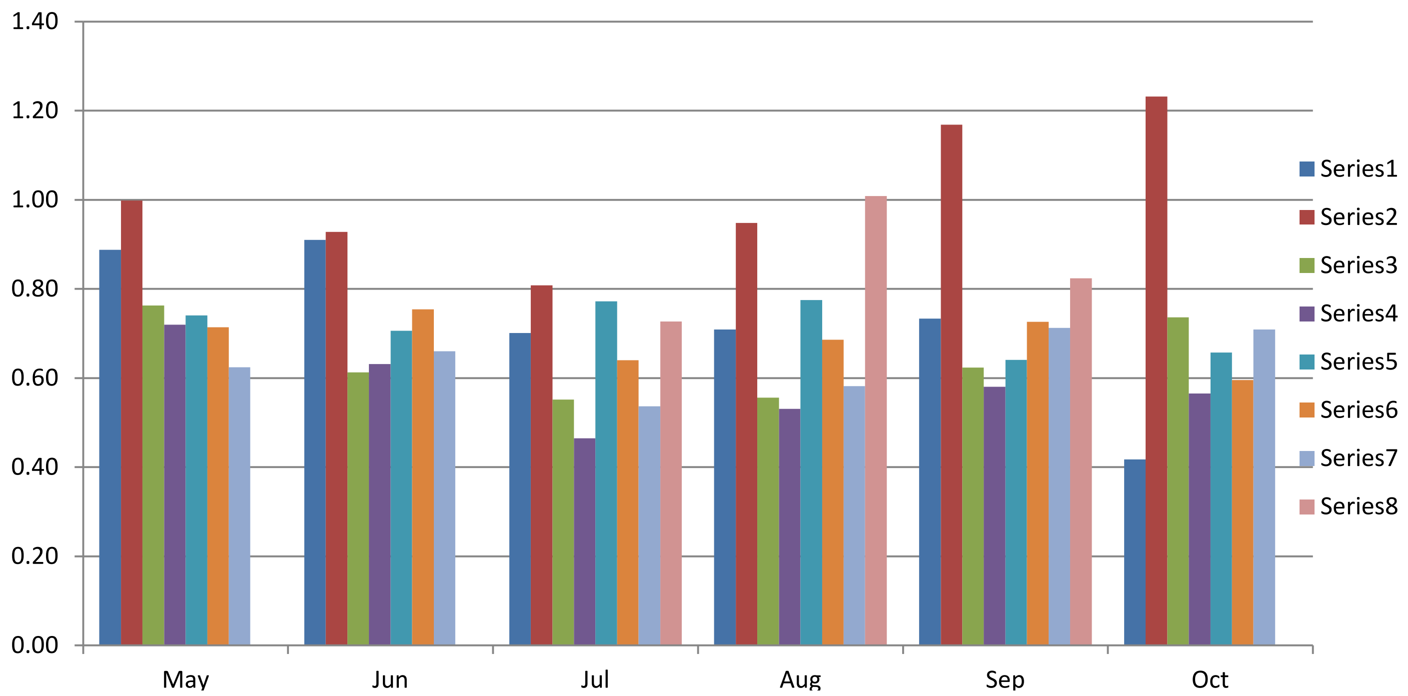


ESTIMATION OF BIAS CORRECTION FACTORS FOR MRCFFG USING DATA FOR THE PERIOD: 2009 - 2012

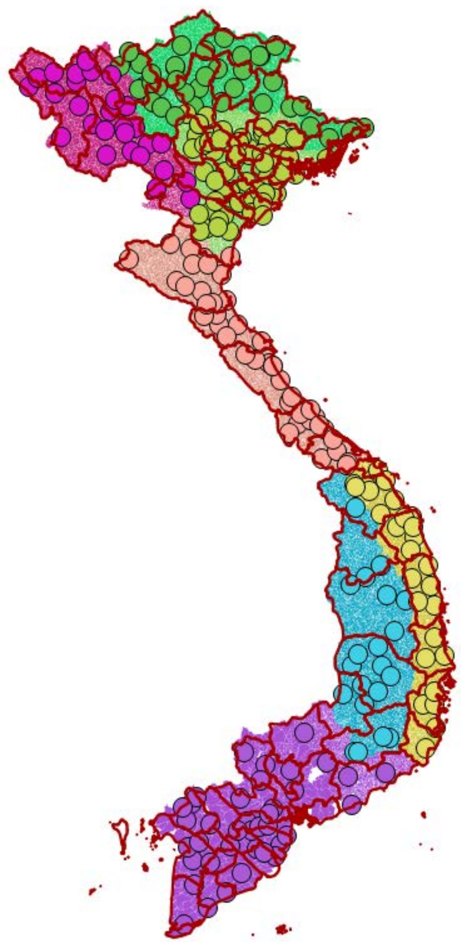
PICHAID VAROONCHOTIKUL[2], VU DUC LONG[3], THERESA M. MODRICK[1], CRISTOPHER SPENCER[1], AND KONSTANTINE P. GEORGAKAKOS[1]



291 gauges



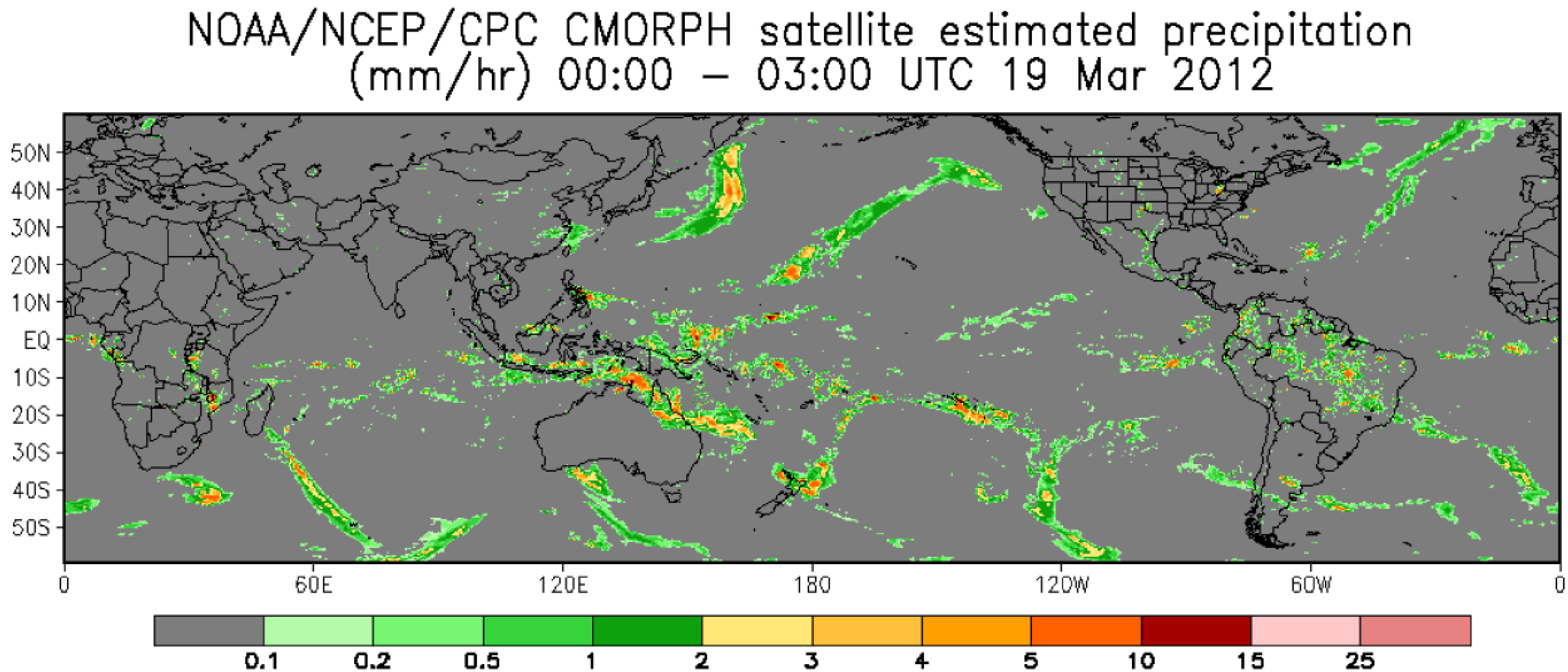
Potential for collaboration with the IMHAM System



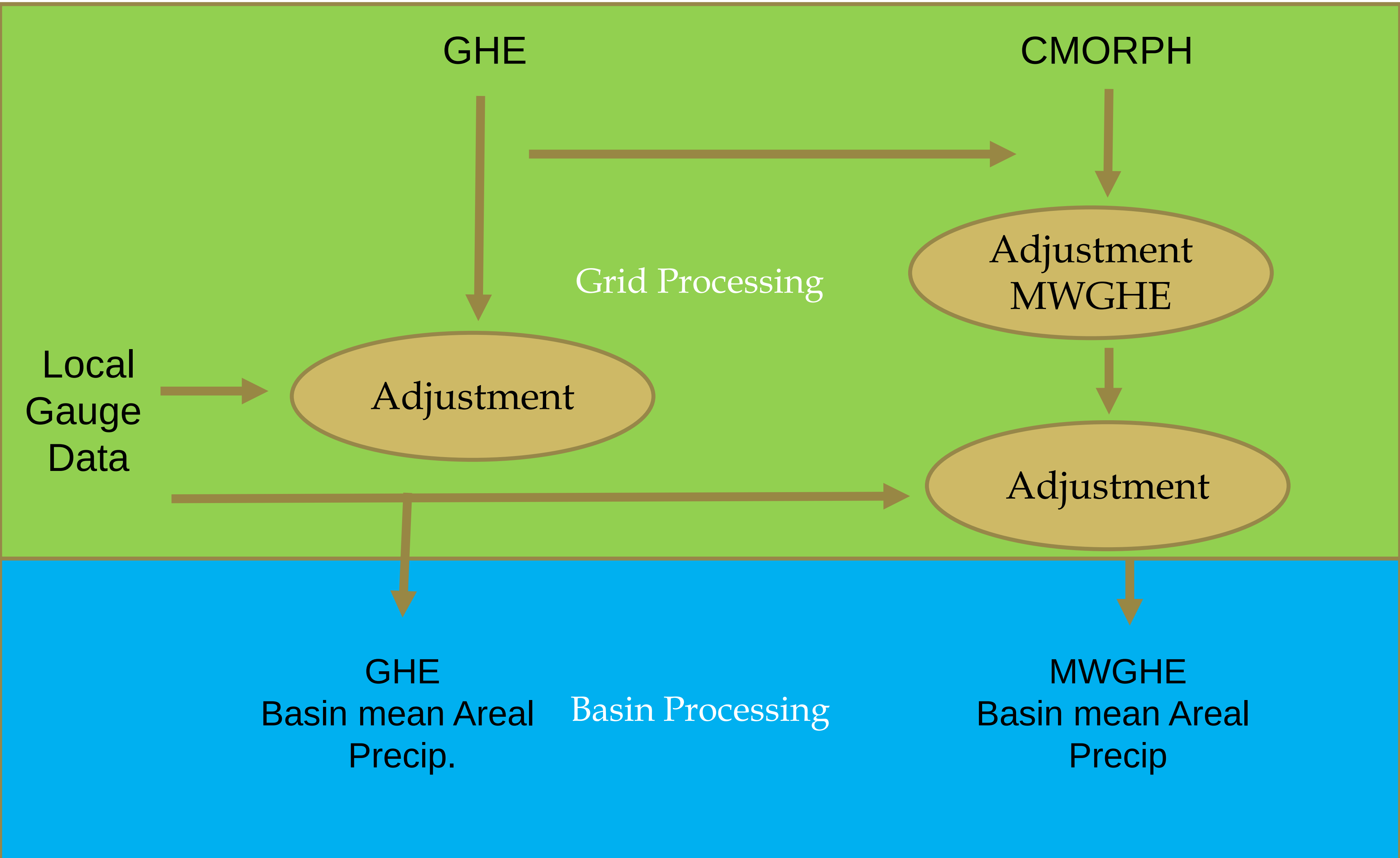
Microwave -based Satellite Precipitation

Climate Prediction Center (CPC) Morphing-Technique (CMORPH)

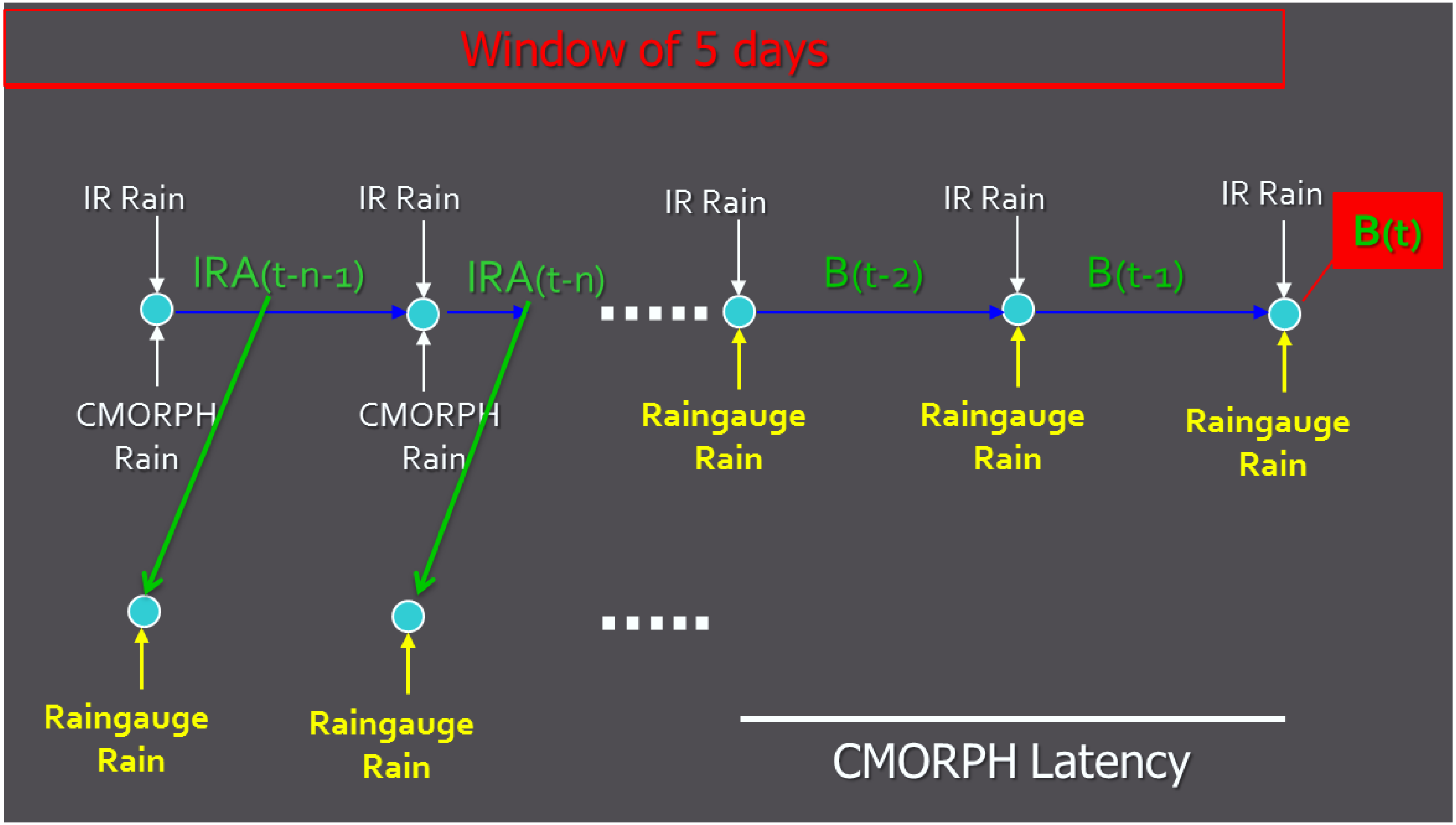
- microwave based estimate of rain rate
- infrared based estimate of motion (wind vector) to interpolate in time



Satellite Rainfall Estimate

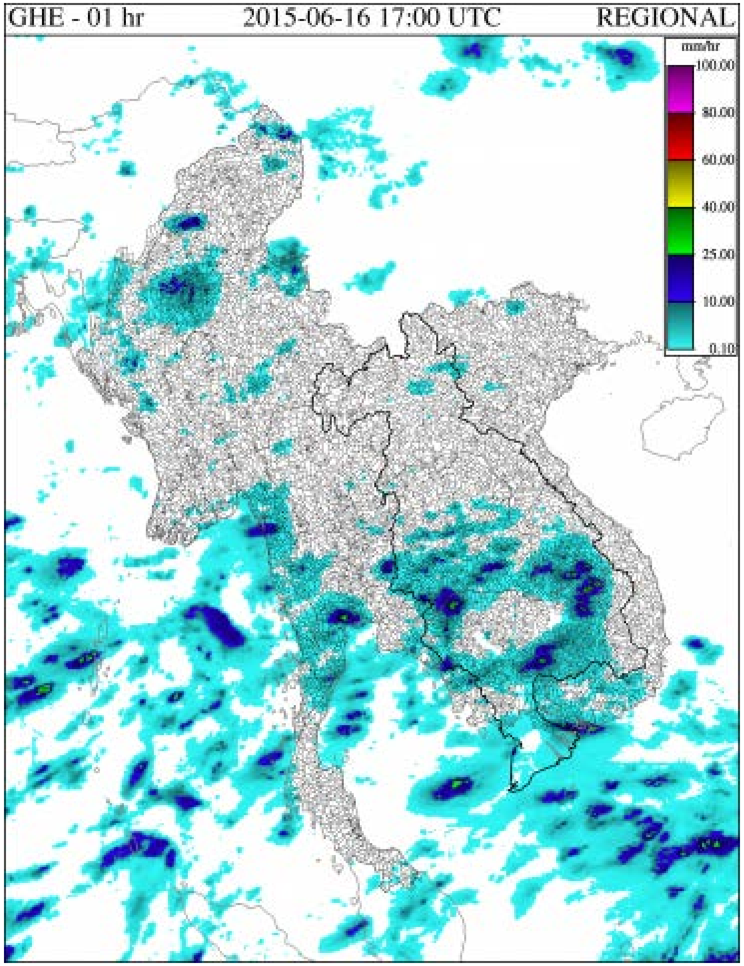


Multi Spectral Satellite Rainfall for FFG System

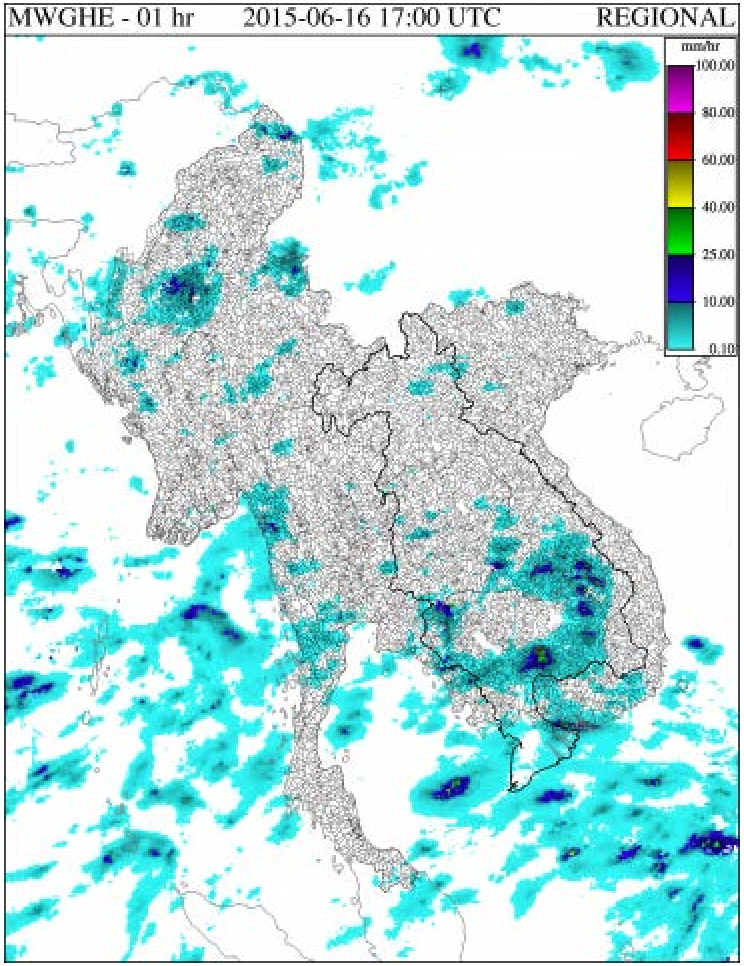


Examples

Original GHE

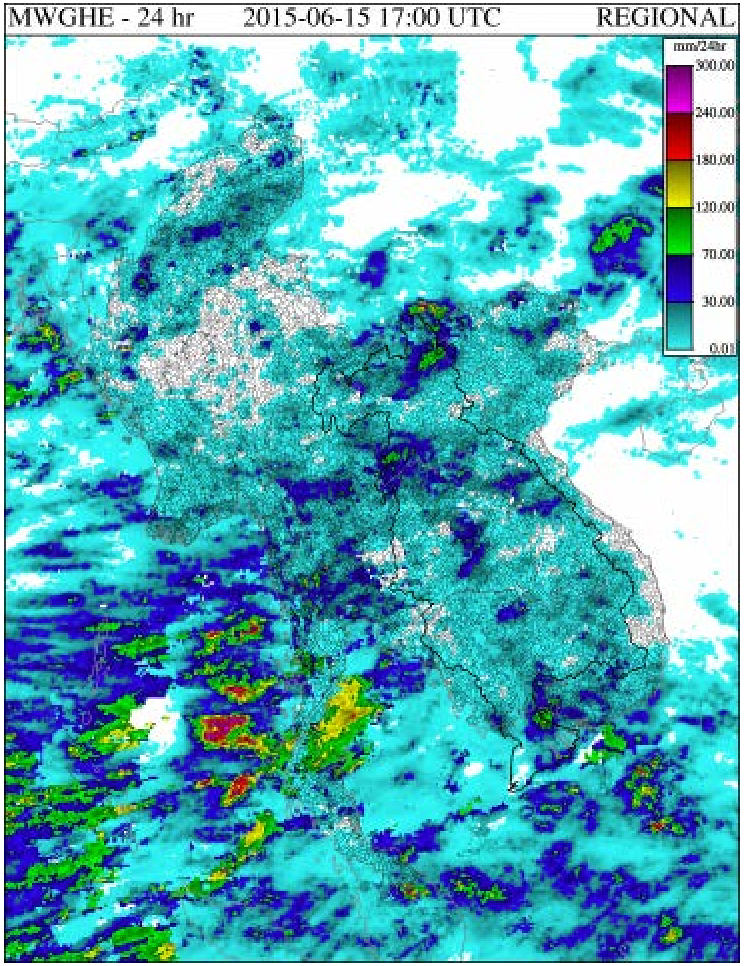


Adjusted GHE

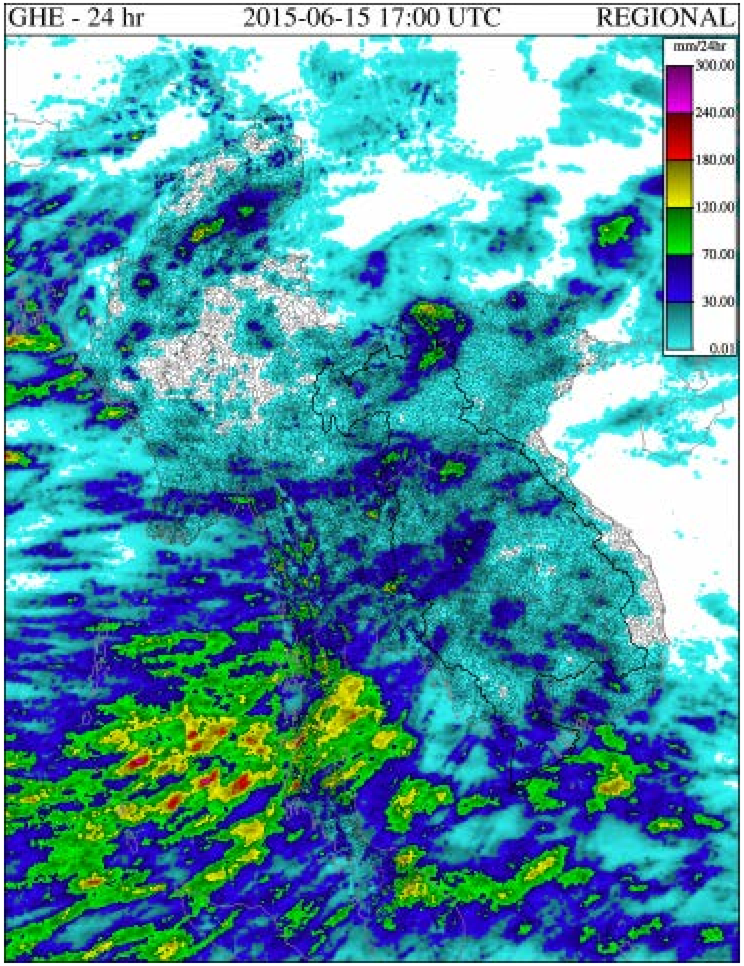


Examples

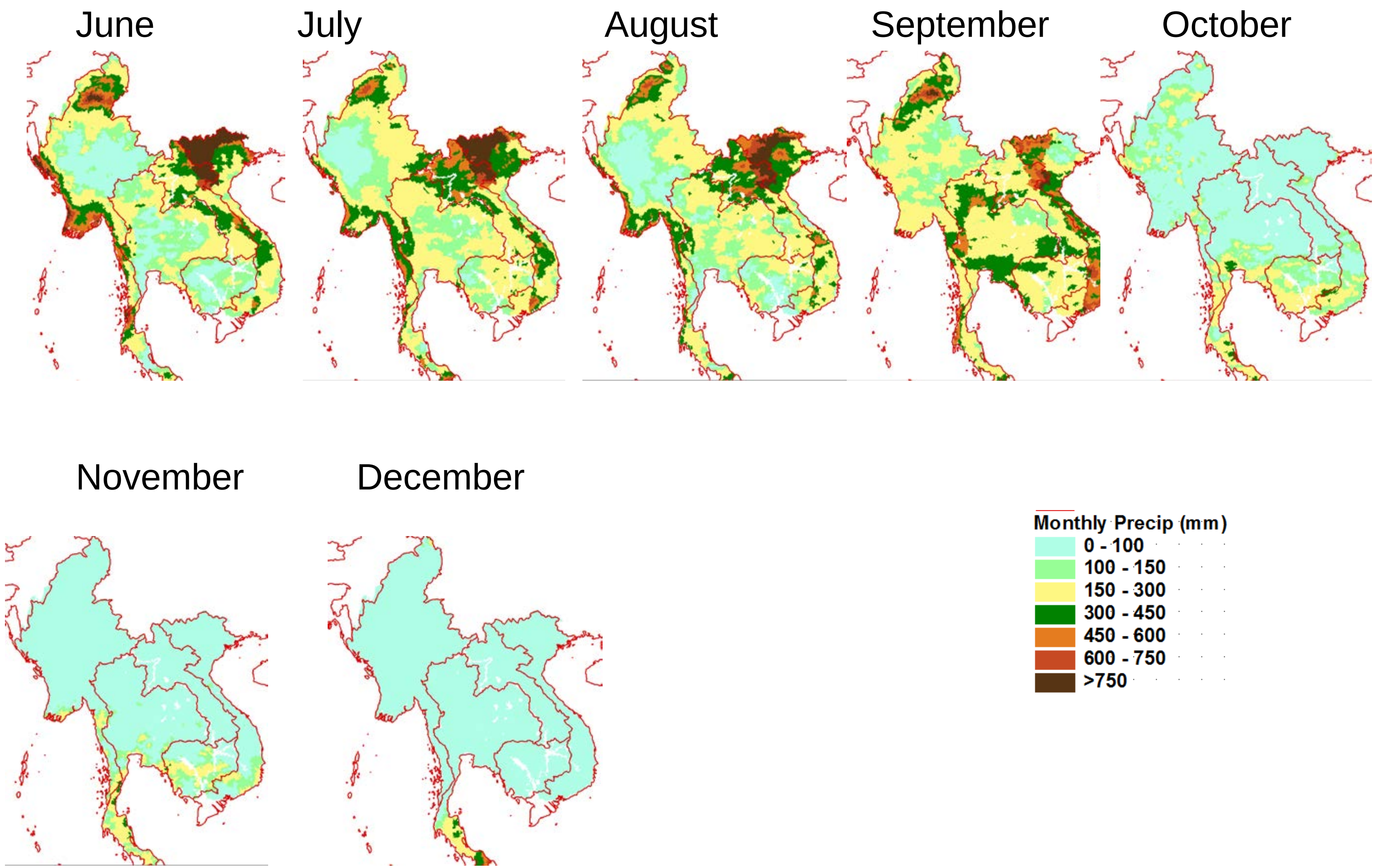
Original GHE



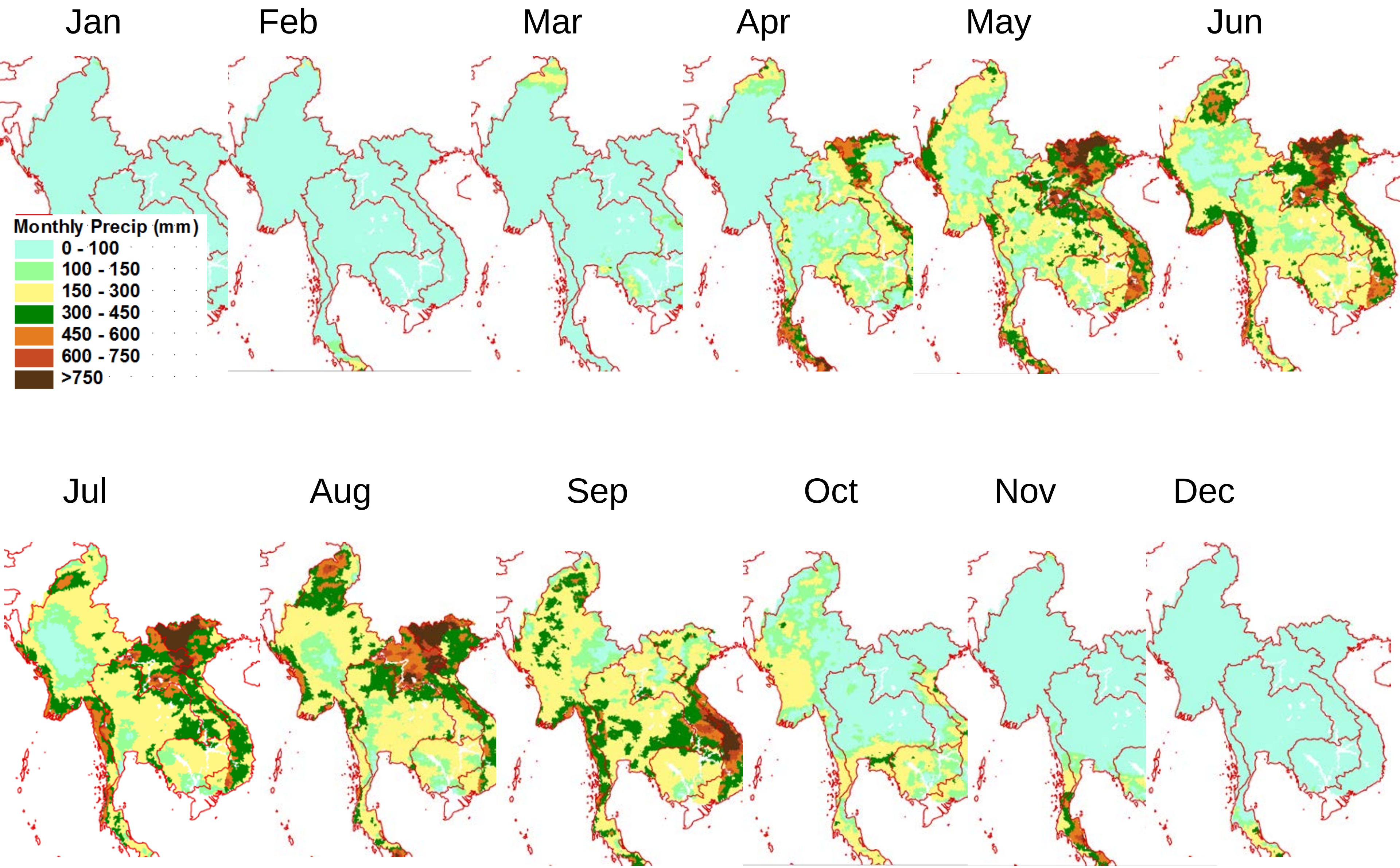
Adjusted GHE



2012

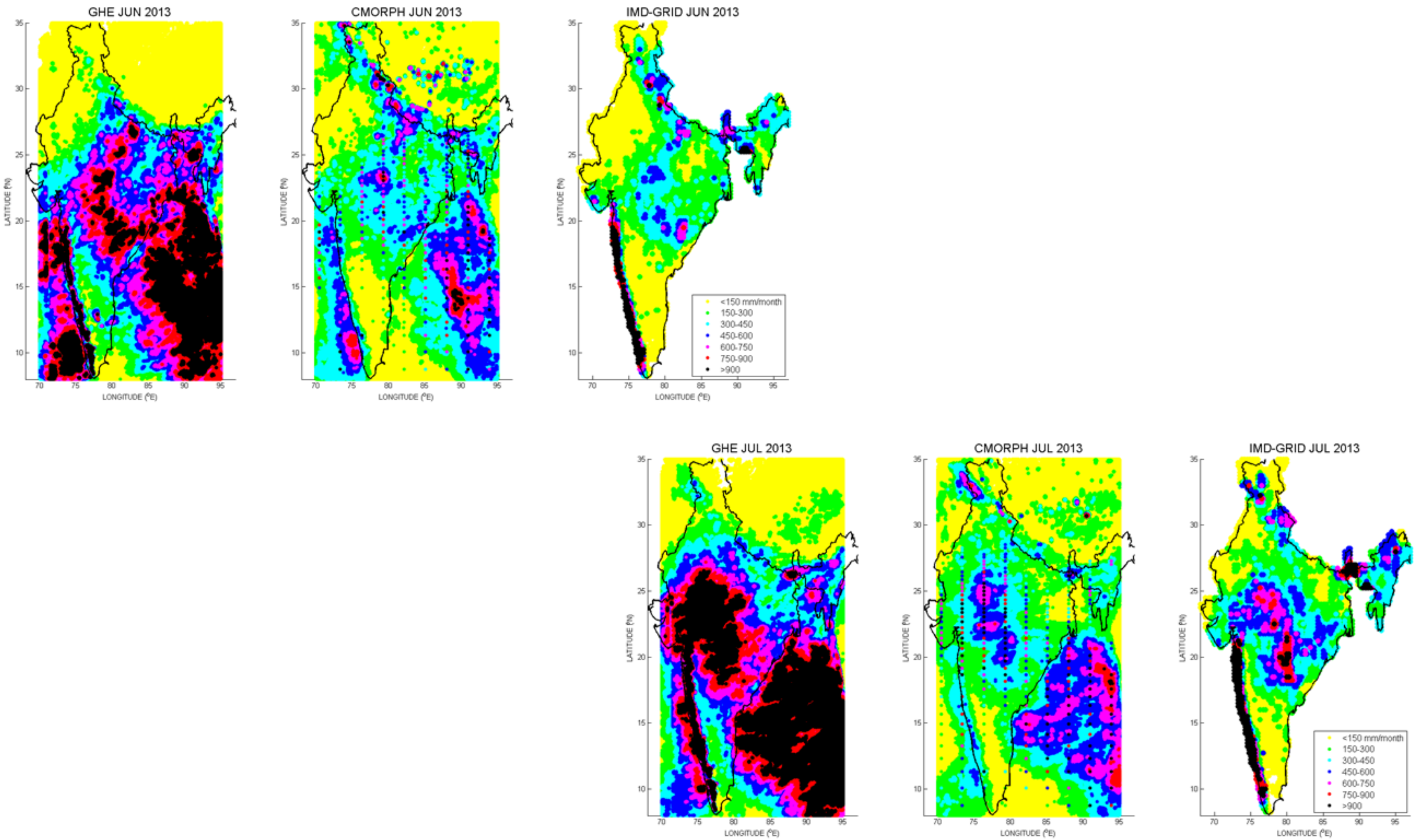

June
July
August
September
October
November
December
Monthly Precip (mm)
0 - 100
100 - 150
150 - 300
300 - 450
450 - 600
600 - 750
>750

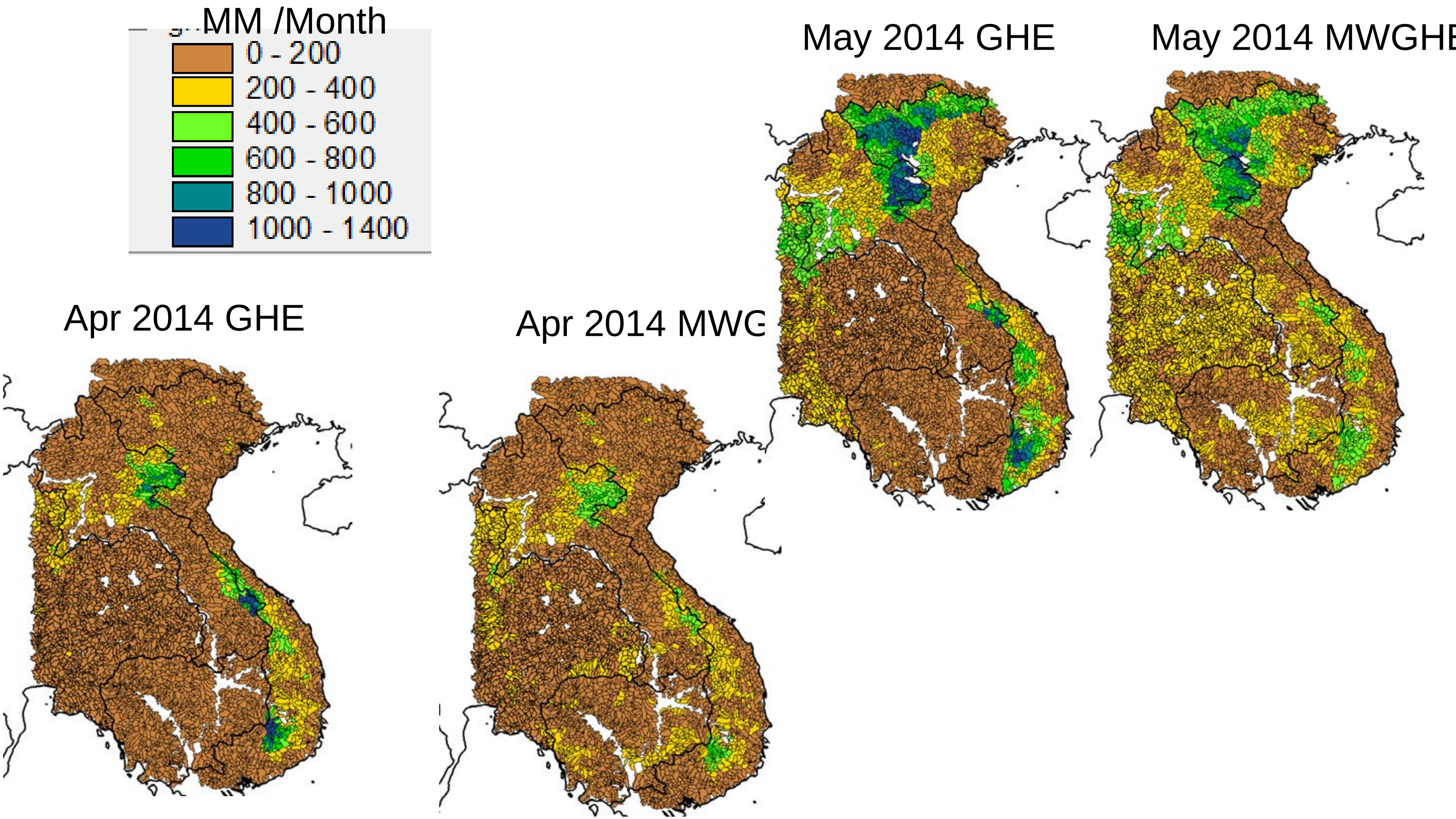
2013



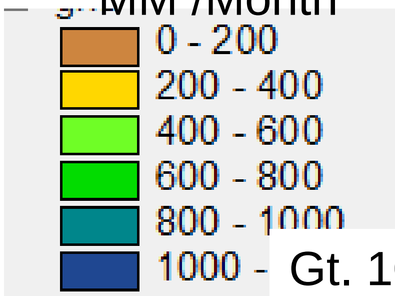
Jan
Feb
Mar
Apr
May
Jun
Monthly Precip (mm)
0 - 100
100 - 150
150 - 300
300 - 450
450 - 600
600 - 750
>750
Jul
Aug
Sep
Oct
Nov
Dec

Validation of CMORPH in Coastal Regions



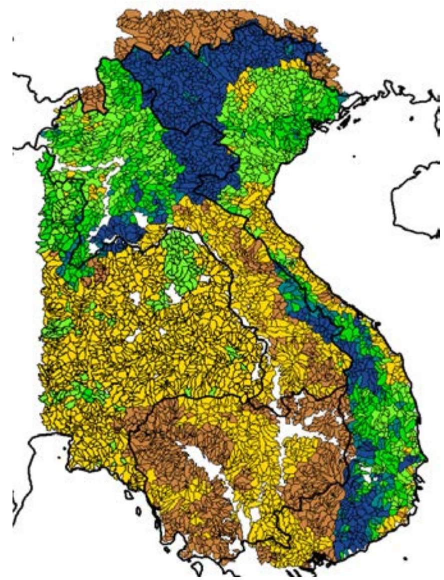

MM /Month
0 - 200
200 - 400
400 - 600
600 - 800
800 - 1000
1000 - 1400
May 2014 GHE
May 2014 MWGHE
Apr 2014 GHE
Apr 2014 MWG

MM /Month

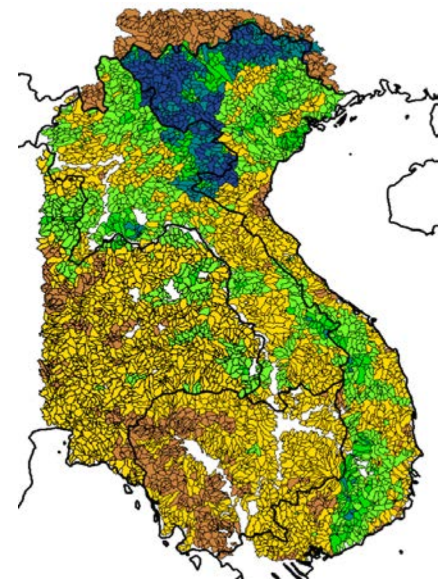


Gt. 1000

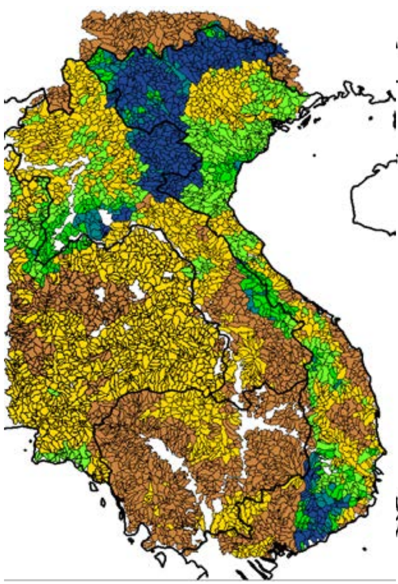
Jul 2014 GHE



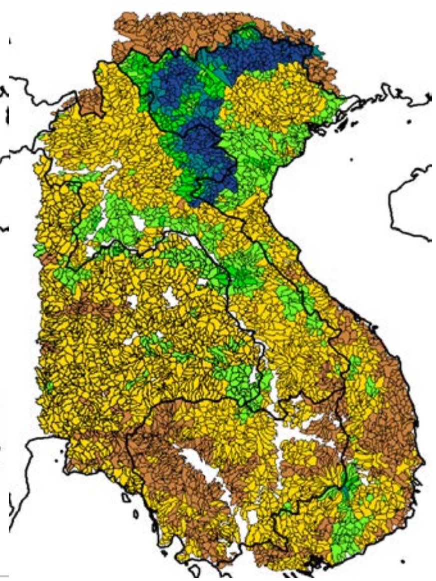
Jul2014 MWGHE

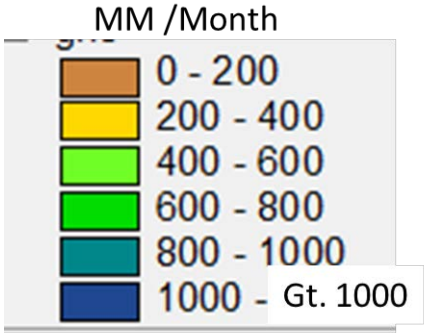


Jun 2014 GHE

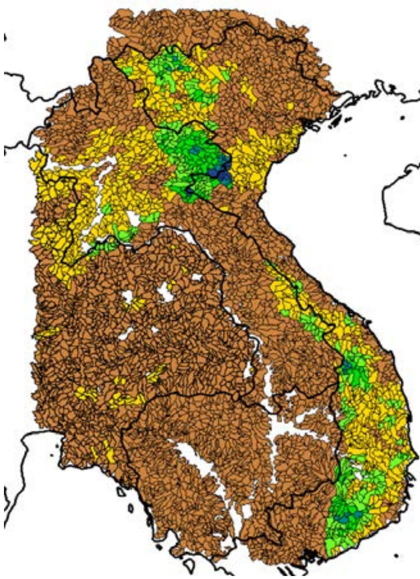


Jun 2014 MWGHE

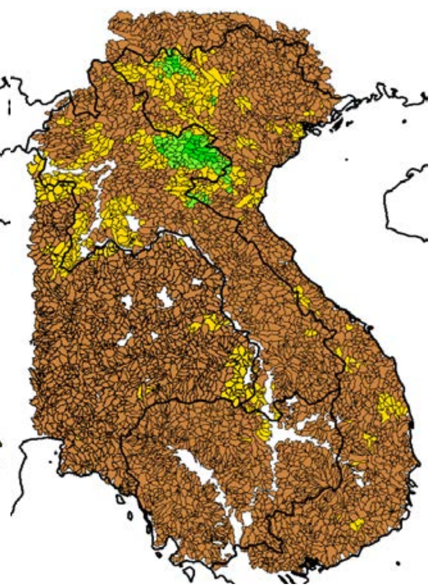




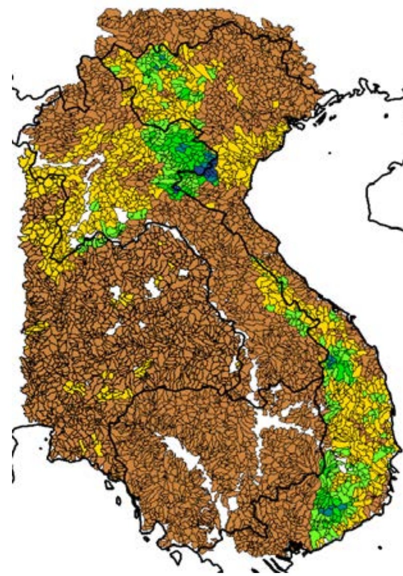
Aug 2014 GHE



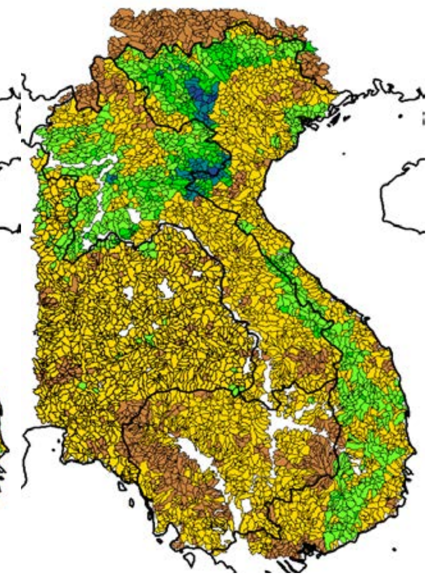
Aug 2014 MWGHE

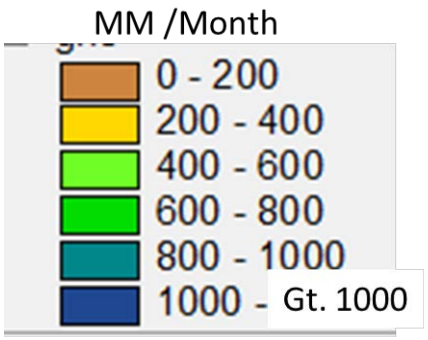


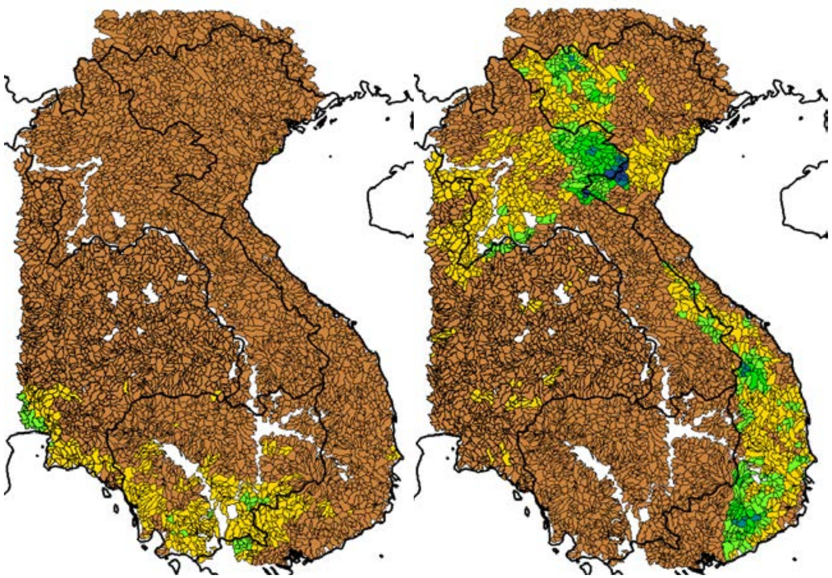
Sep 2014 GHE

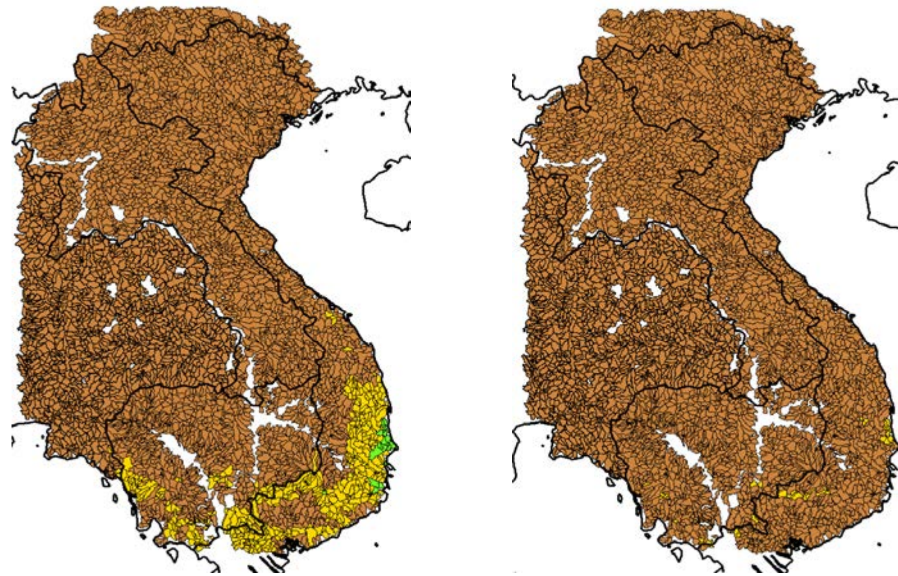


Sep 2014 MWGHE

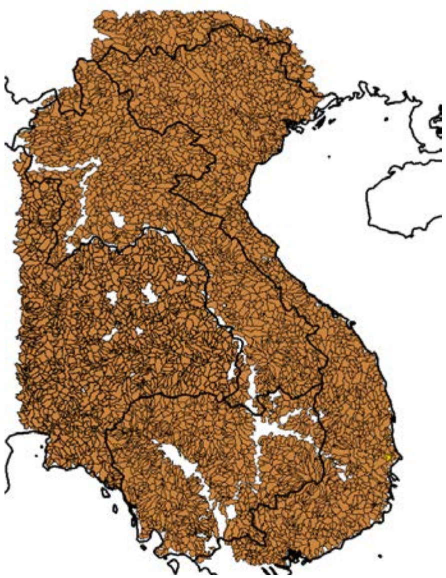



MM /Month
0 - 200
200 - 400
400 - 600
600 - 800
800 - 1000
1000 -
Gt. 1000

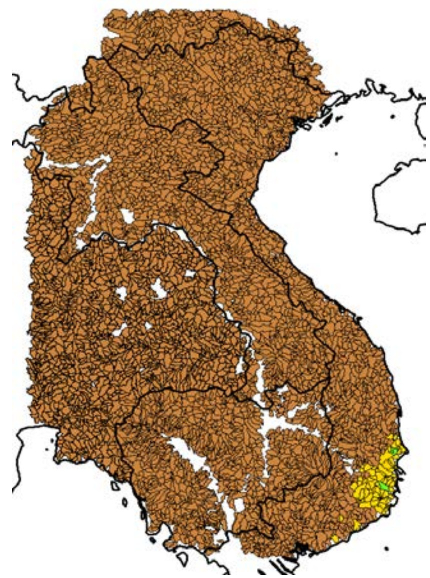


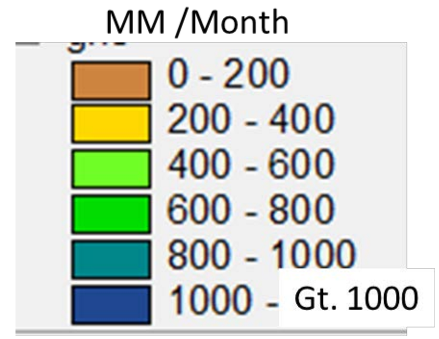


Dec 2014 GHE



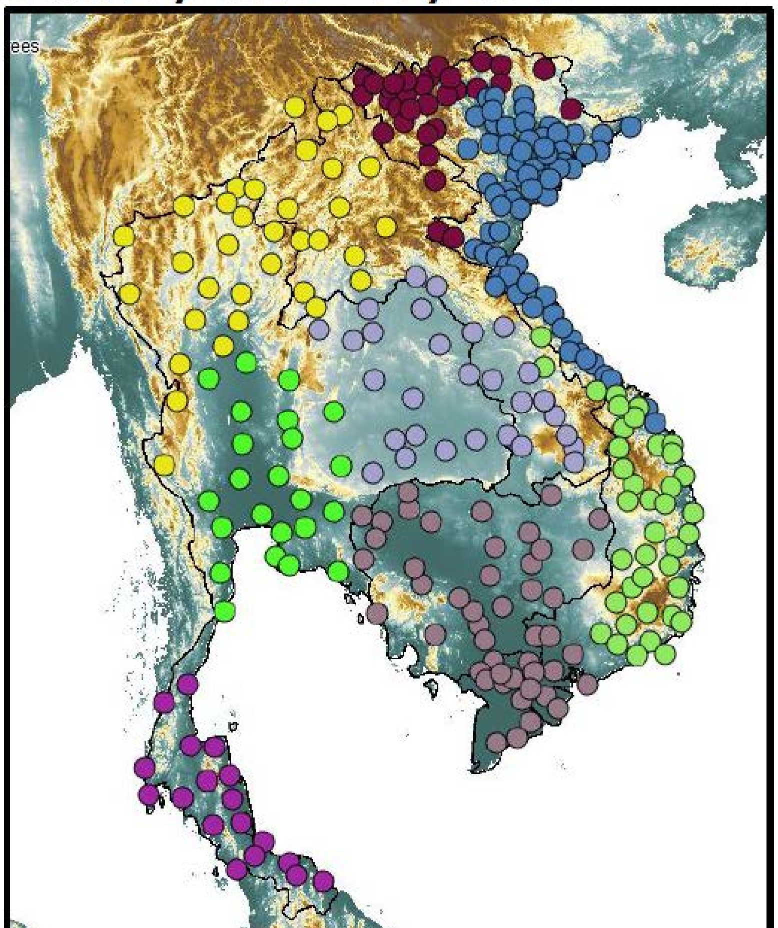
Dec 2014 MWGHE

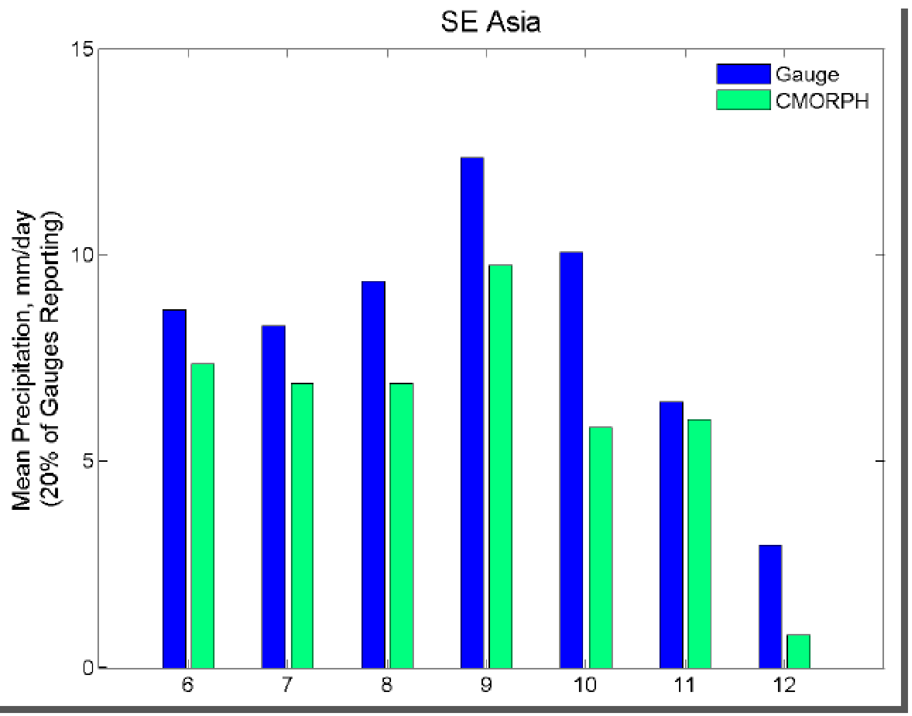




CMORPH Climatological Bias

Analysis for SE Asia Region
(291 gauges, 8 sub-regions)
Period: 6/2011 – 12/2011





Magnitude Dependent Adjustment