Climate Change Assessment & Adaptation

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Outline of Presentation

- Background
- Objectives
- Study Framwork
- WEB-DHM application of Kalu Ganga Basin
- GCM Selection
- Bias-correction Method
- Downscaling Method
- Results
- Conclusion & Discussion

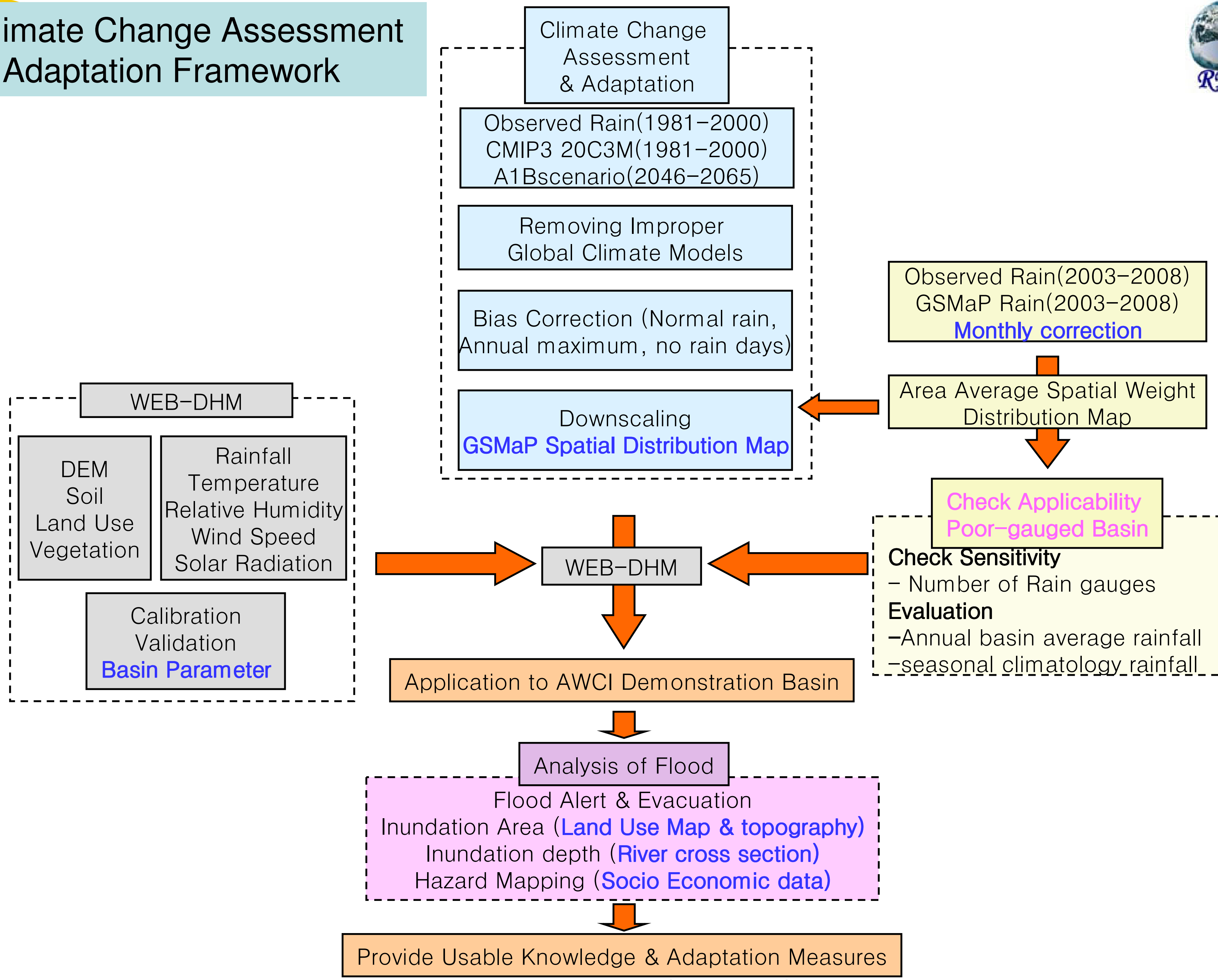
BACKGROUND

- By 2050,fresh water availability in Central, South, East and South-East Asia particularly in large river basins is projected to decrease. (IPCC AR4)
- Population growth, industrial development, and agriculture are causing societies to face serious challenges in allocation scarce water resources to **increasing demands**. (IPCC, 2001)
- Climate change impact assessment on water resources is essential for planning of future Integrated Water Resources Management (IWRM) strategies. (IPCC,2001)
- It is necessary to focus on **long term analysis for basin scale** water balance due to climate change impacts on regional hydrologic process.

Objectives

- To understand the climate change impacts on water resources in basin scale (20 years analysis for past and future)
- To investigate long-term precipitation trend, frequency and subsequence changes in stream flow regimes under the global warming A1B scenario (WEB-DHM)
- To monitor the possibility of flooding and socio-economic loss due to flood risk in near future
- To provide the basic adaptation strategies and usable knowledge to cope with Integrated Water Resource Management and Decision Making for Policy makers in future

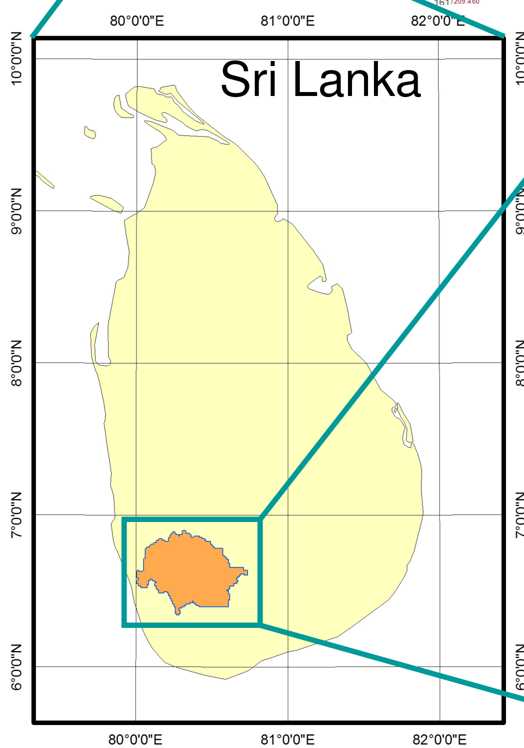
Climate Change Assessment & Adaptation Framework

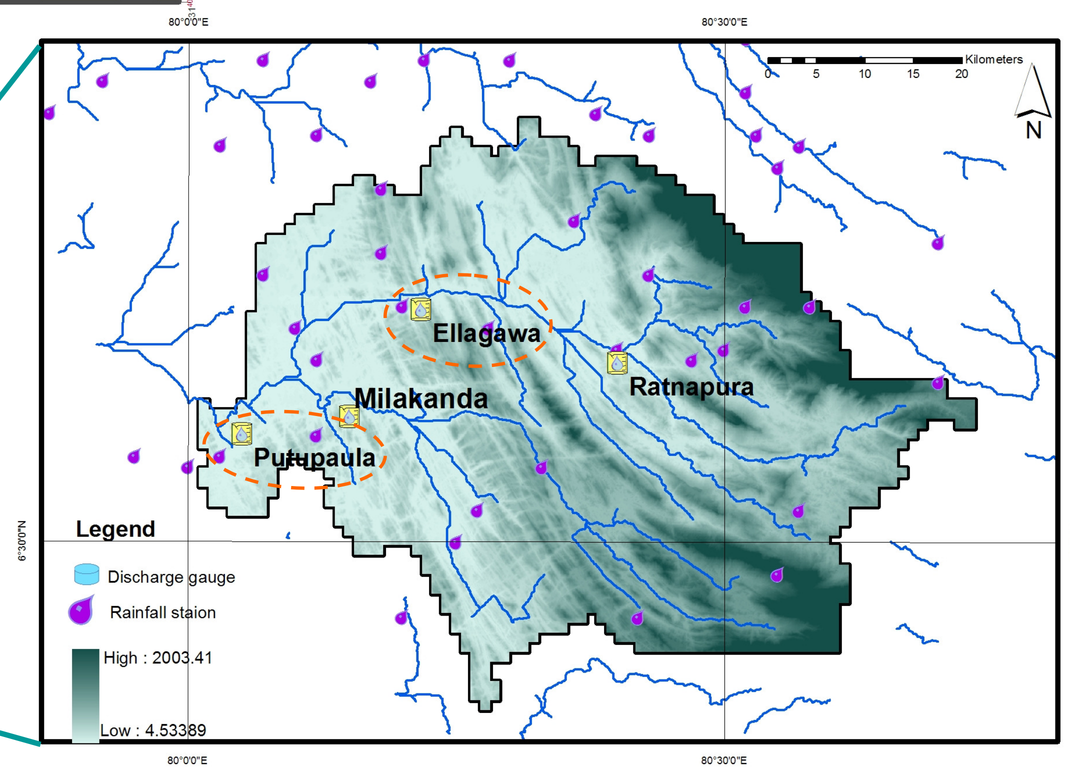


CMIP3 : Coupled Modeled Intercomparison Project Phase-3

20C3M : 20th Century Numerical Reproductive Experiment

Kalu Ganga River Basin

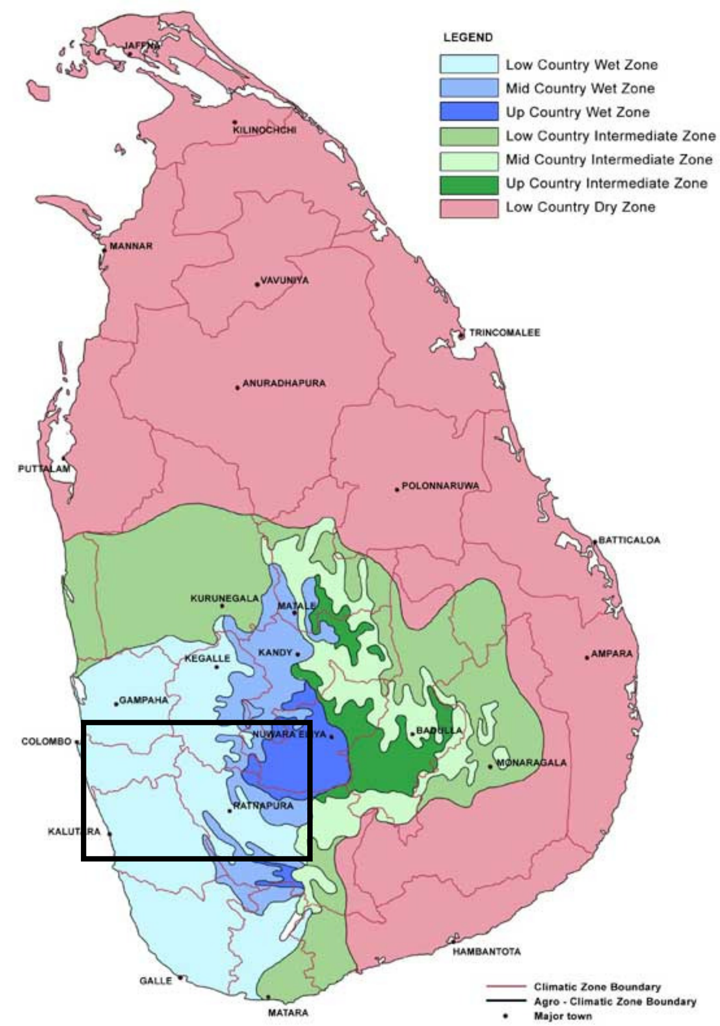




Kalu Ganga Basin Characteristic

- 2nd largest river basin in Sri Lanka
- located in wet zone and high annual average rainfall 4000mm
- 2766 km^2
- Largest amount of annual per capita water availability about 7750m^3 (National level 2300m^3)
- Steep gradient in upstream and mild gradients in downstream
- Its lower flood plain suffer from frequent flood in the Southwest monsoon season
- Densely populated in lower flood plain and a potential area for rice production

Map 3: Agro - climatic Zones of Sri Lanka

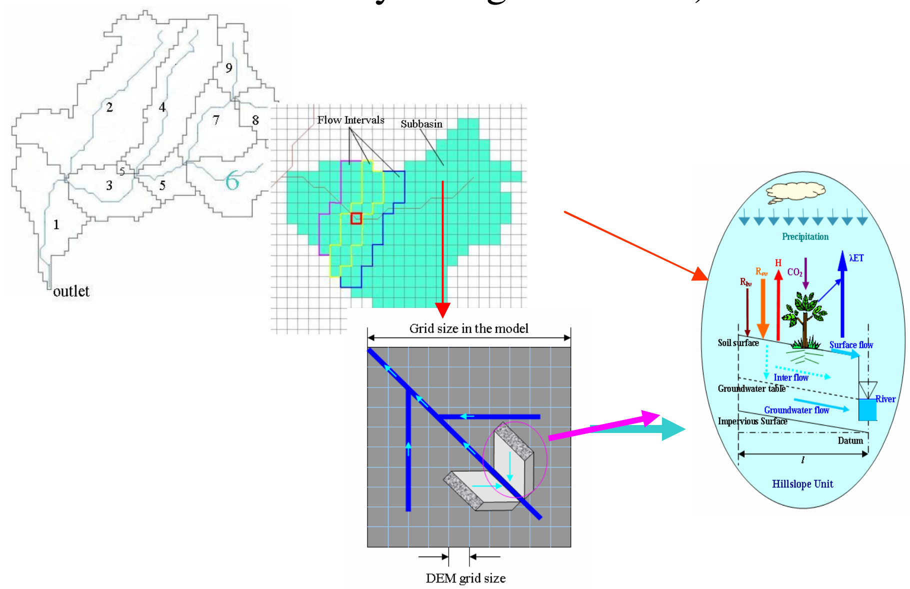


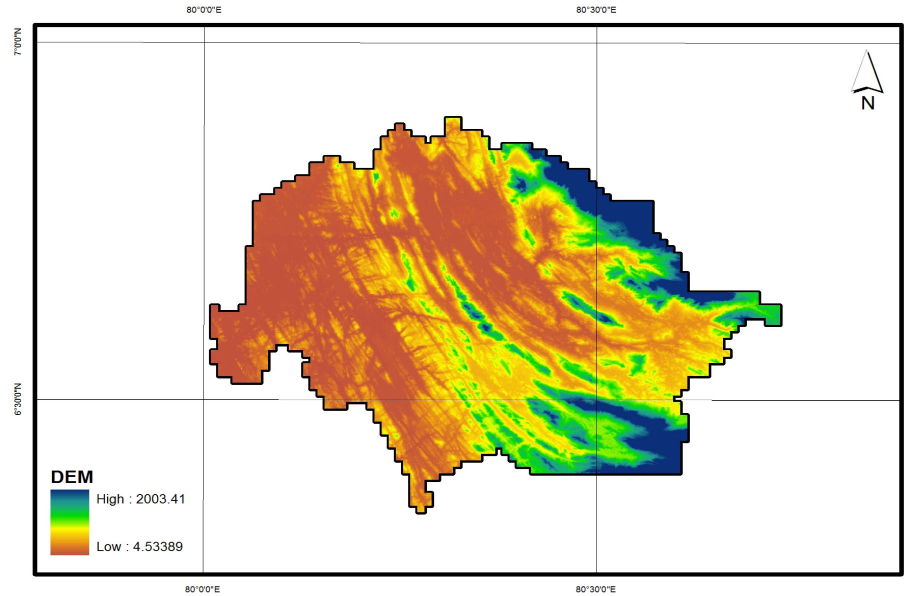
Ampitiyawatta & Shenglian (2009)

Source :Department of Agriculture, Sri Lanka(DOASL)

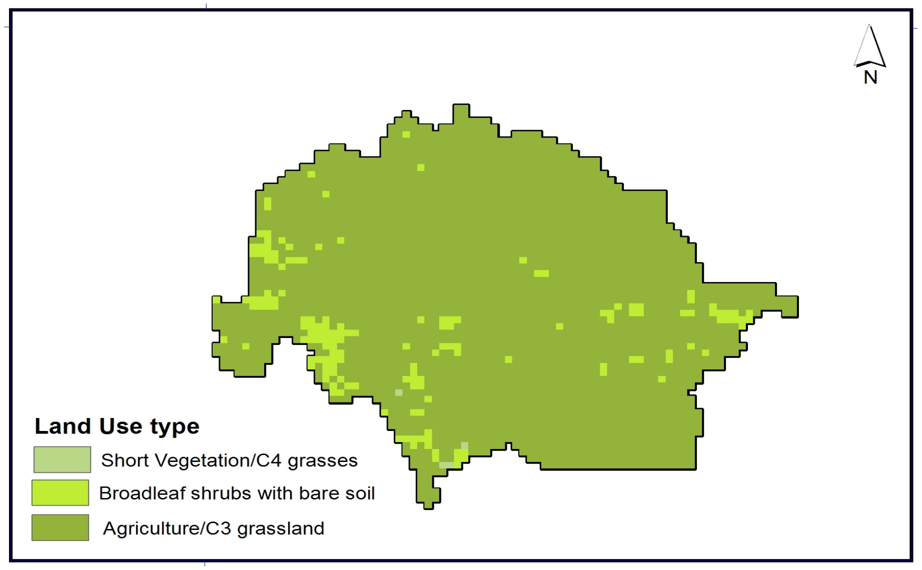
WEB-DHM

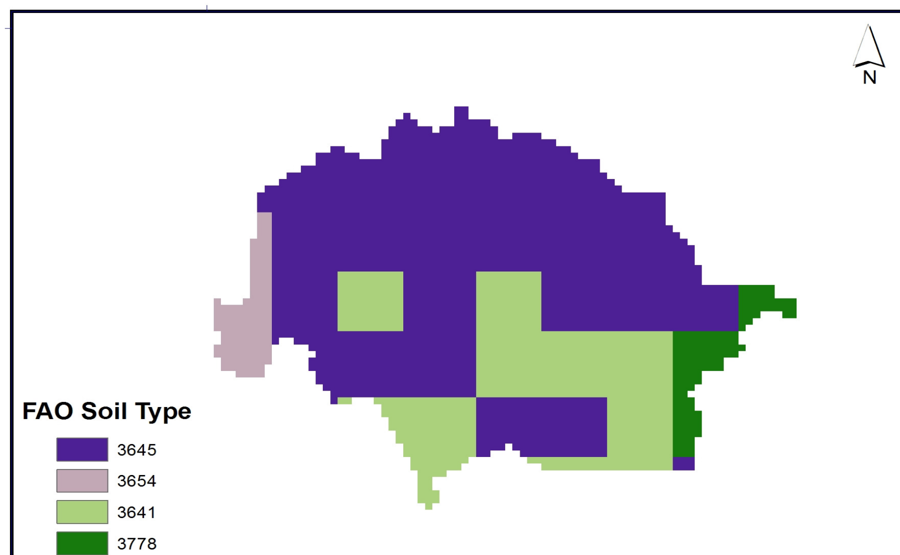
(Water and Energy Budget-based Distributed Hydrological Model)



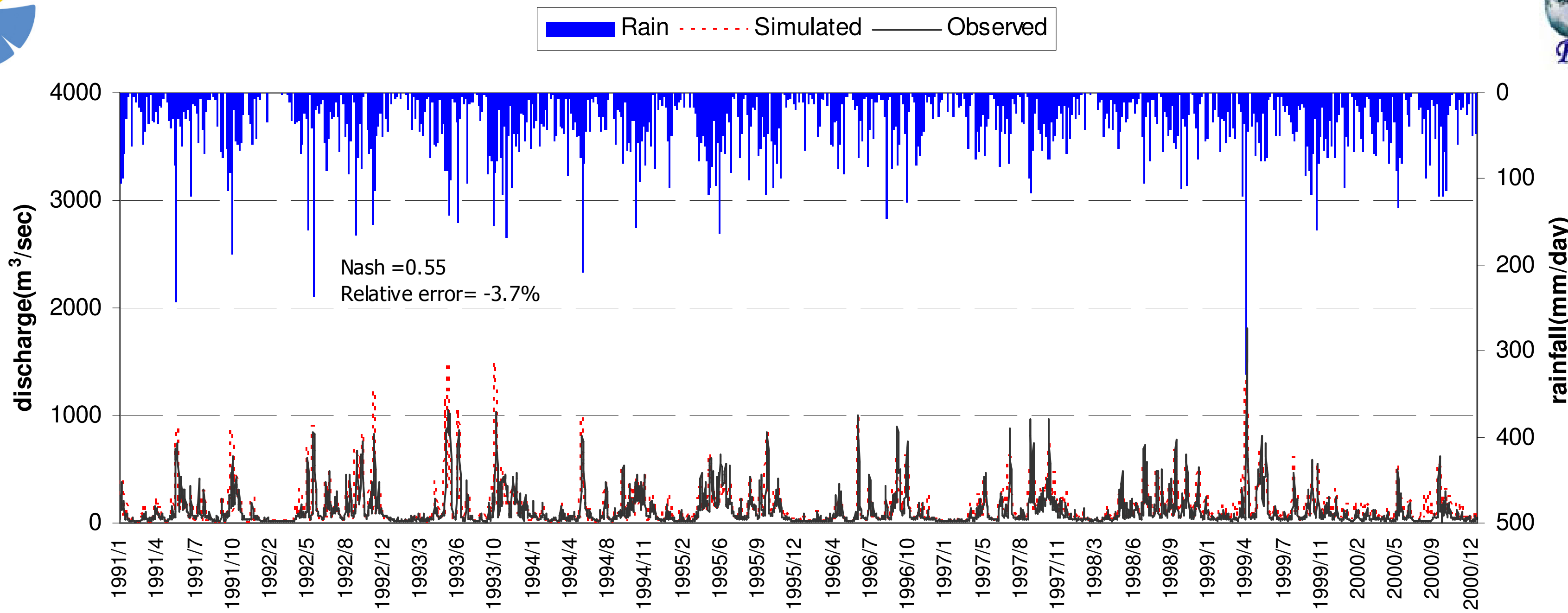


Developed by Lei Wang, 2007

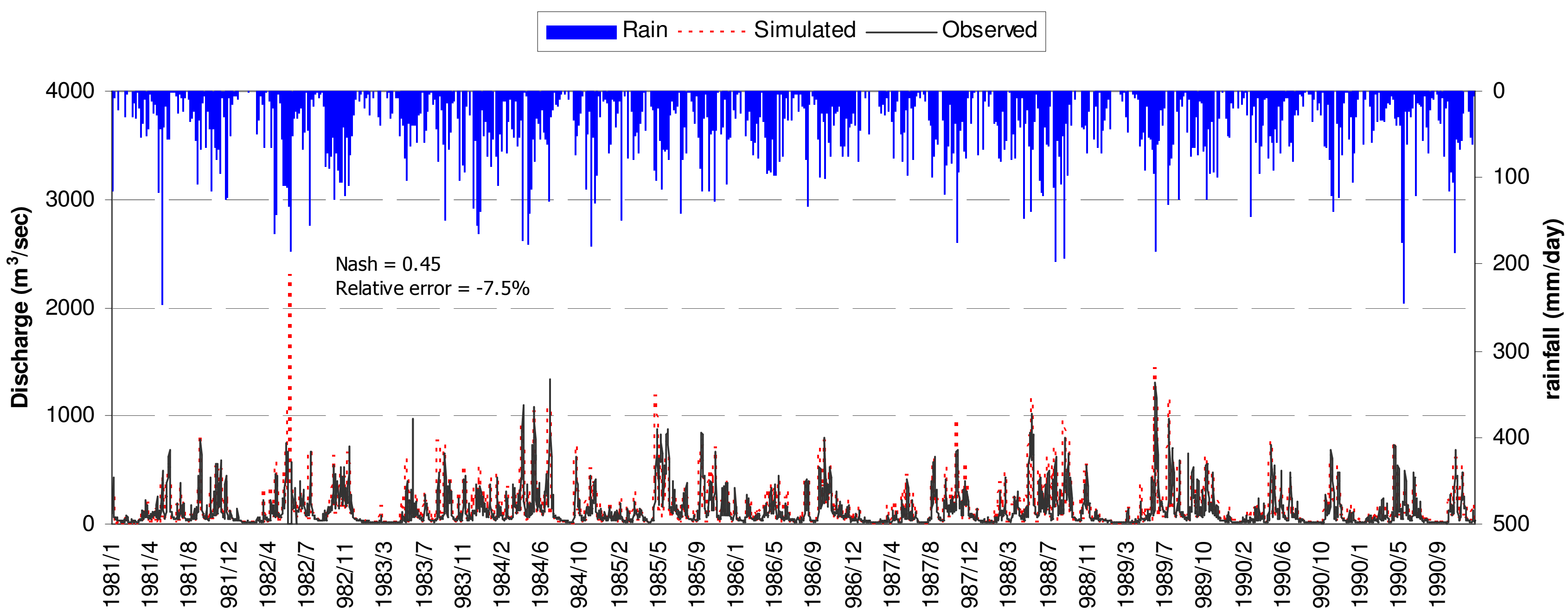




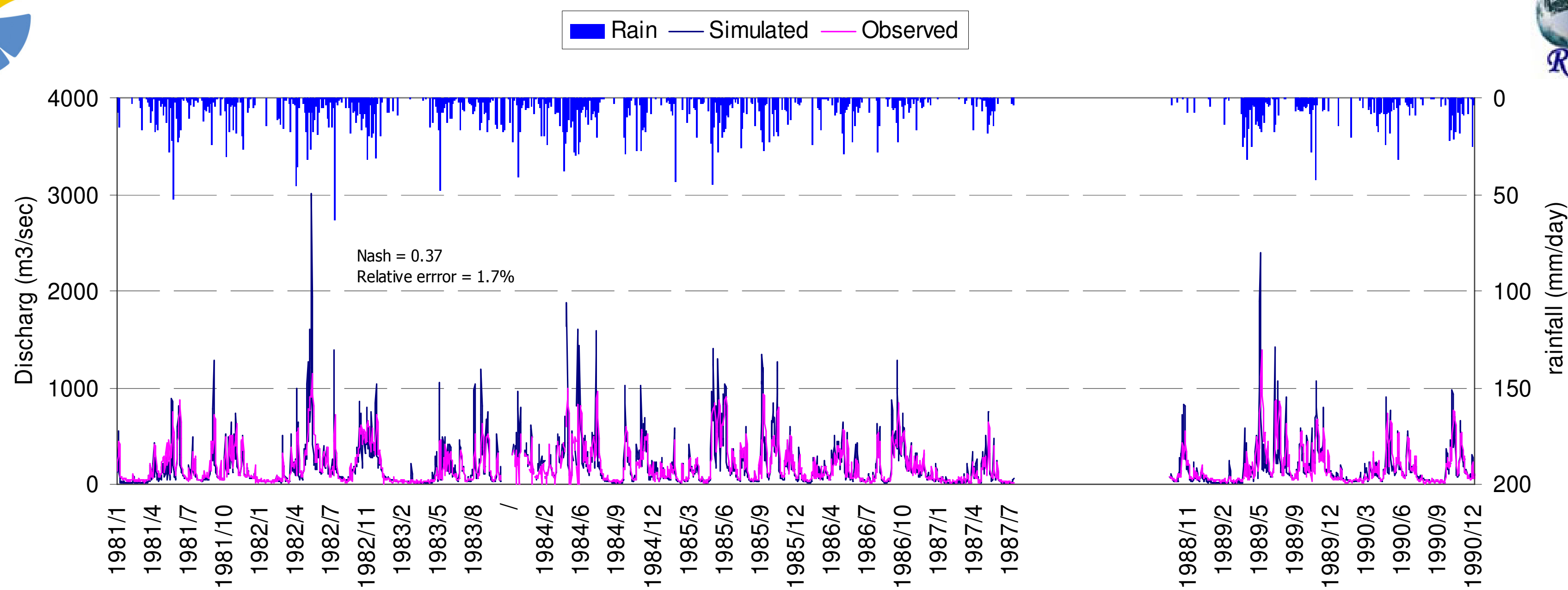
Cailibration at Ellagawa (1991-2000)



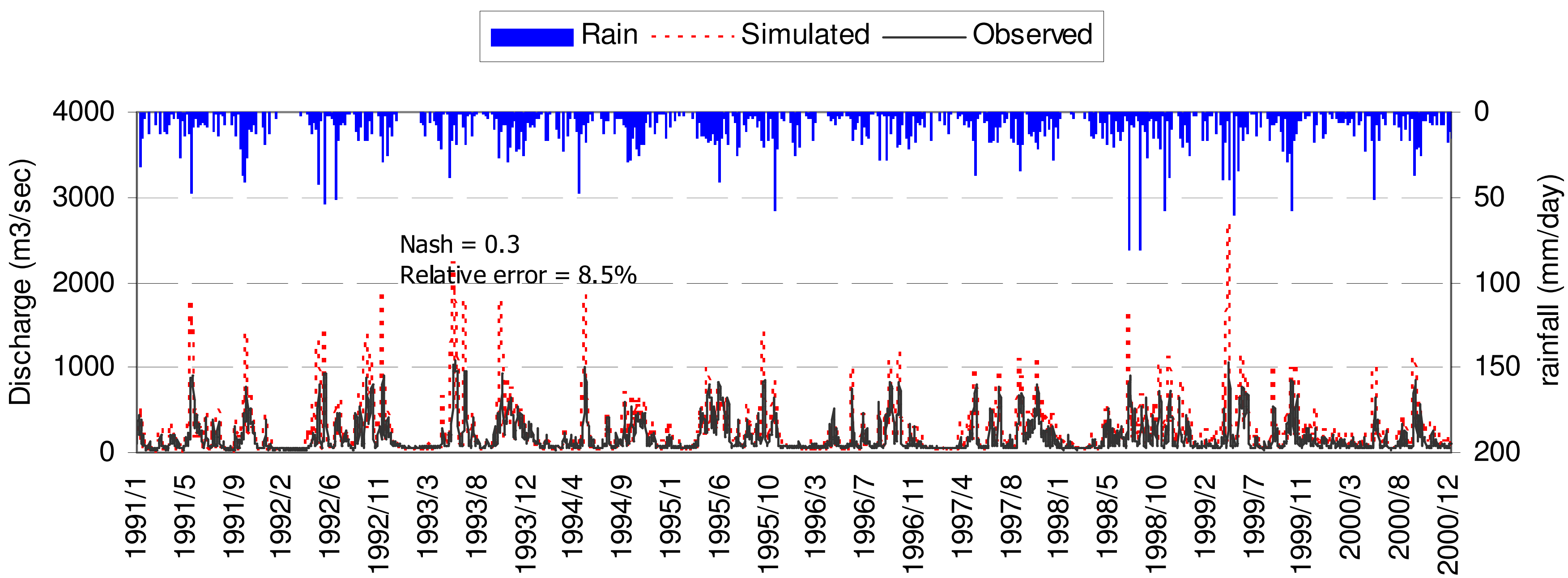
Validation at Ellagawa (1981-1990)



Validation at Putupaula (1981-1990)

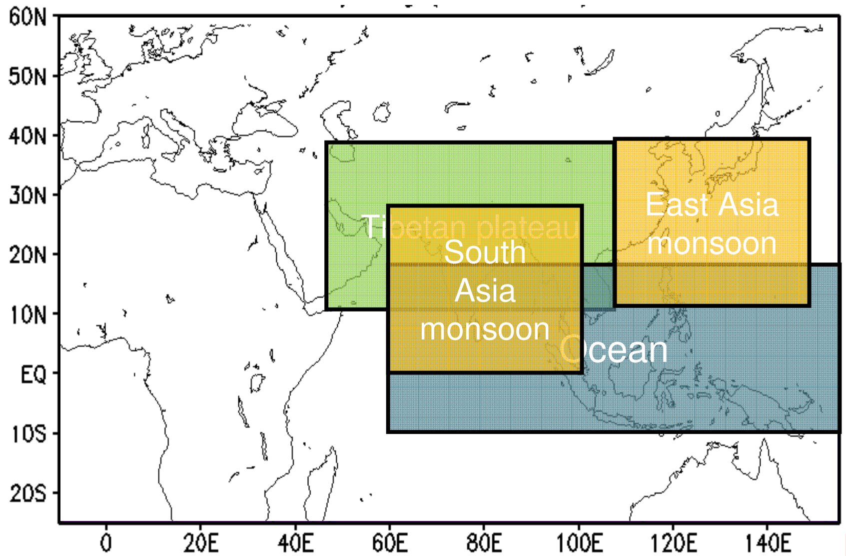


Validation at Putupaula (1991-2000)

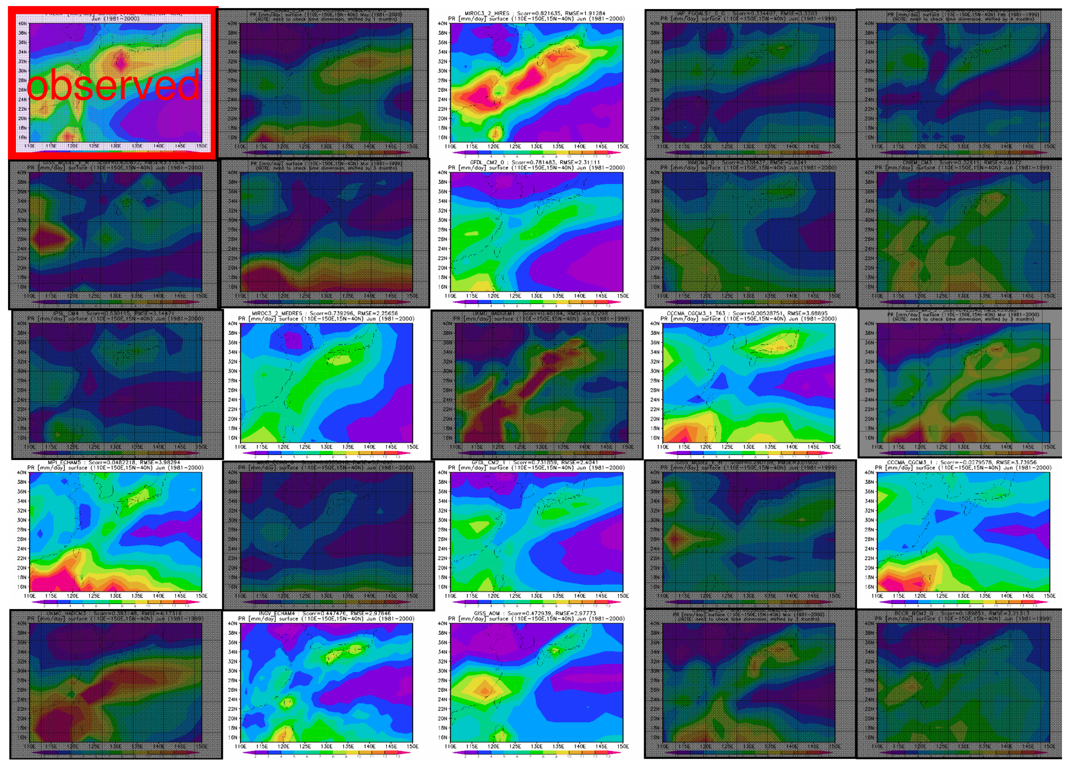


GCM Selections

Region and Parameter

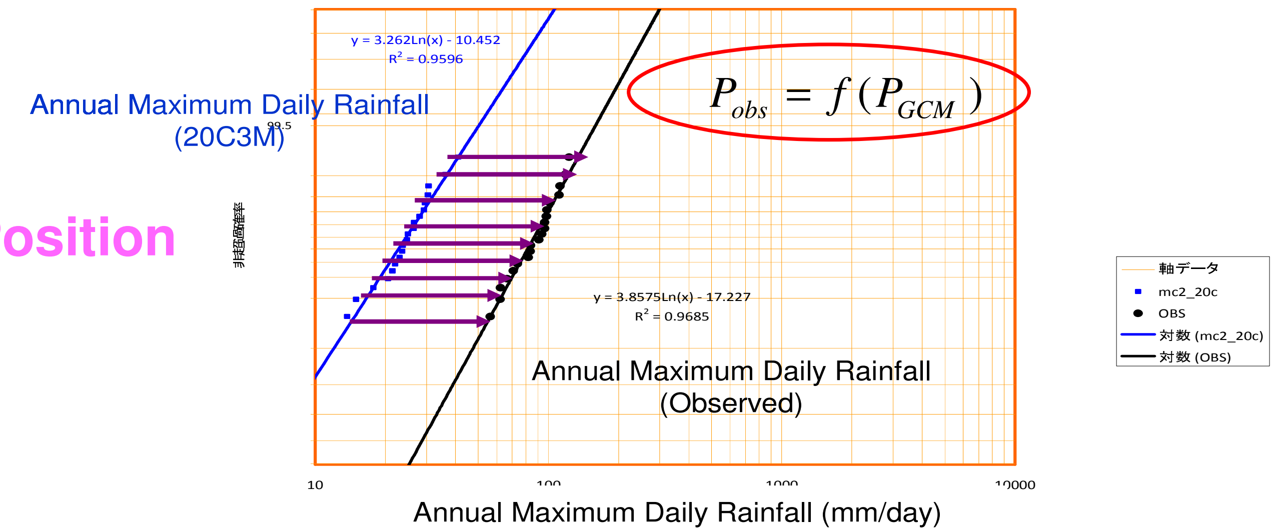


- ✓Spatial distribution of 10 parameters
- ✓ 4 region
- ✓May - August
- ✓ Monthly Spatial Correlation
- ✓Monthly Root mean square error



Bias Correction Methods for Annual maximum Raifall

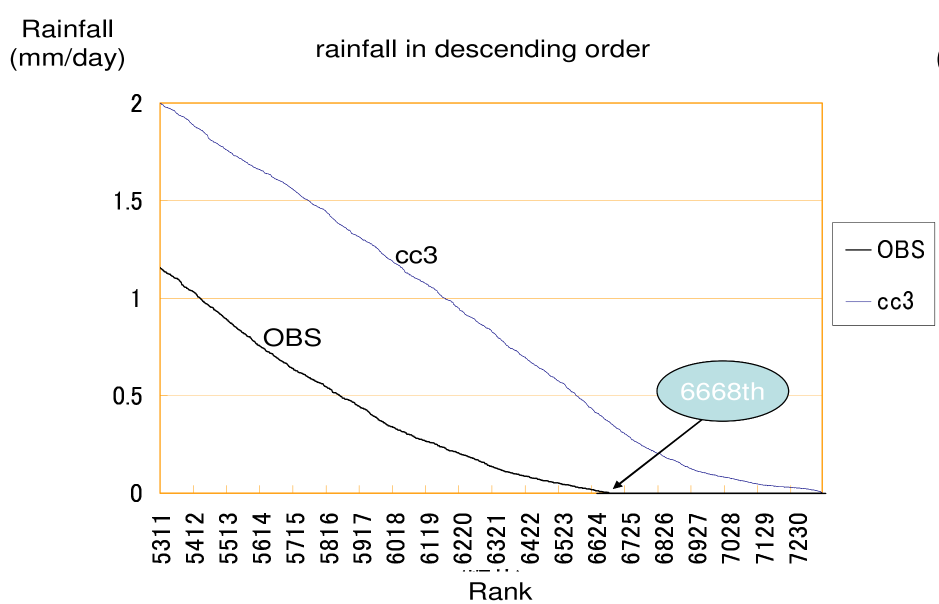
Plotting Position

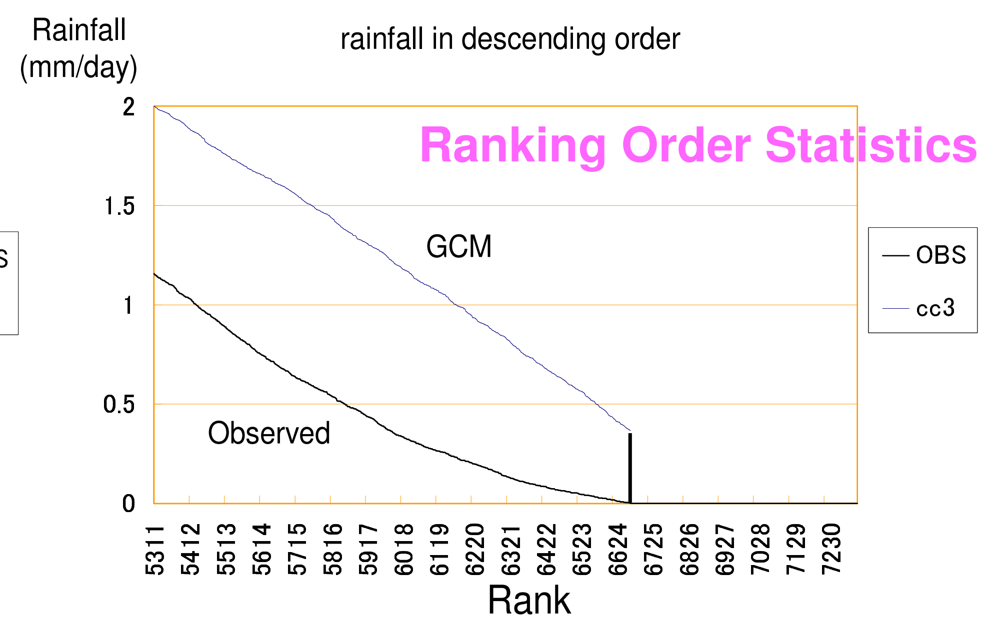


P_{GCM} : Heavy Rainfall in GCM

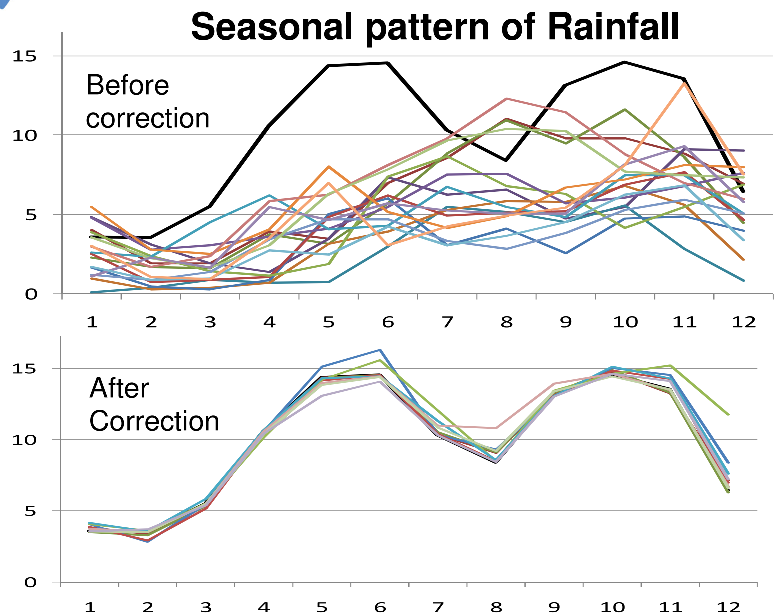
P_{obs} : Heavy Rainfall in Obs

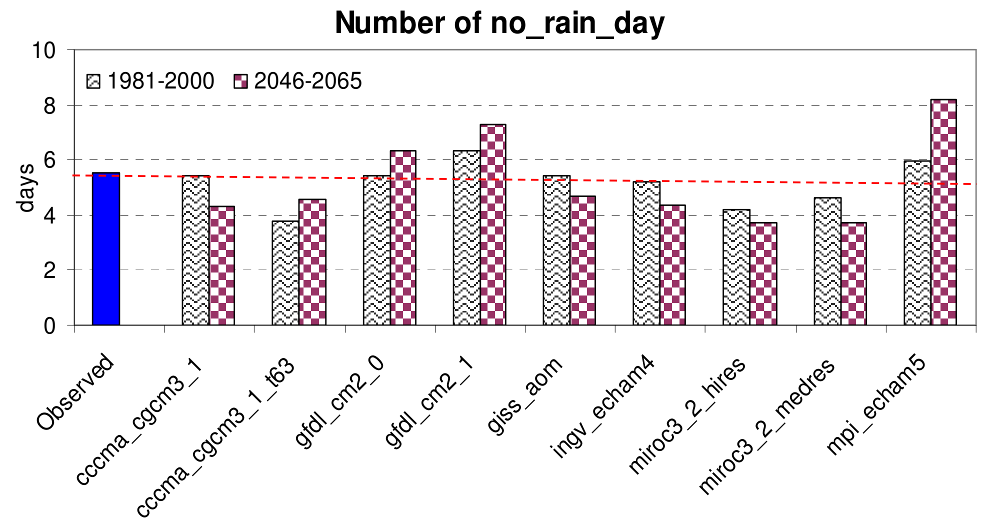
Bias Correction Methods for No Rain Days

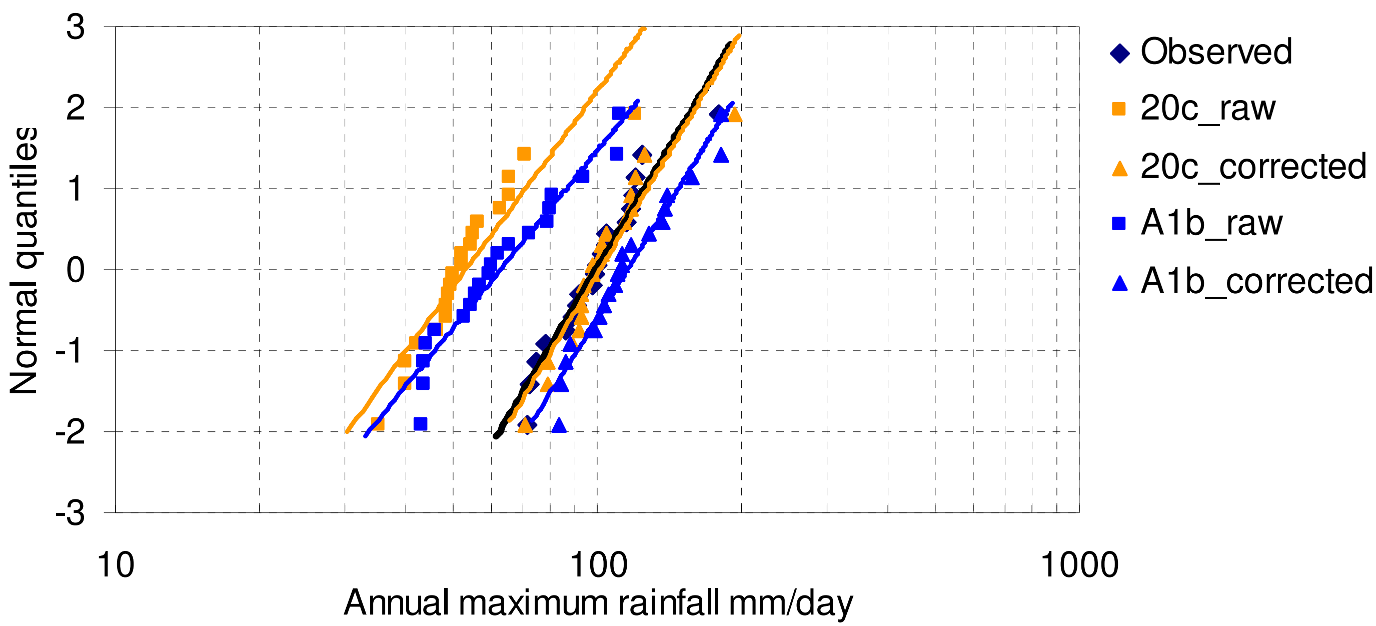




Bias Corrected Rainfall

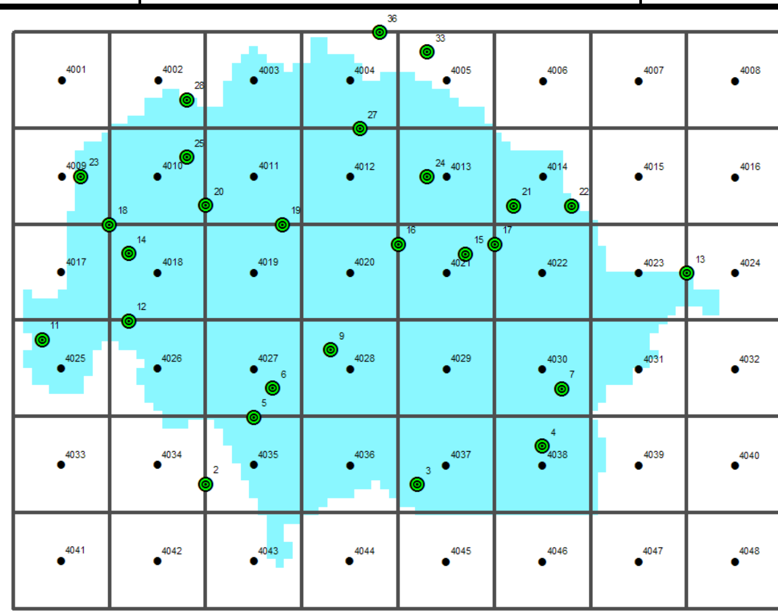


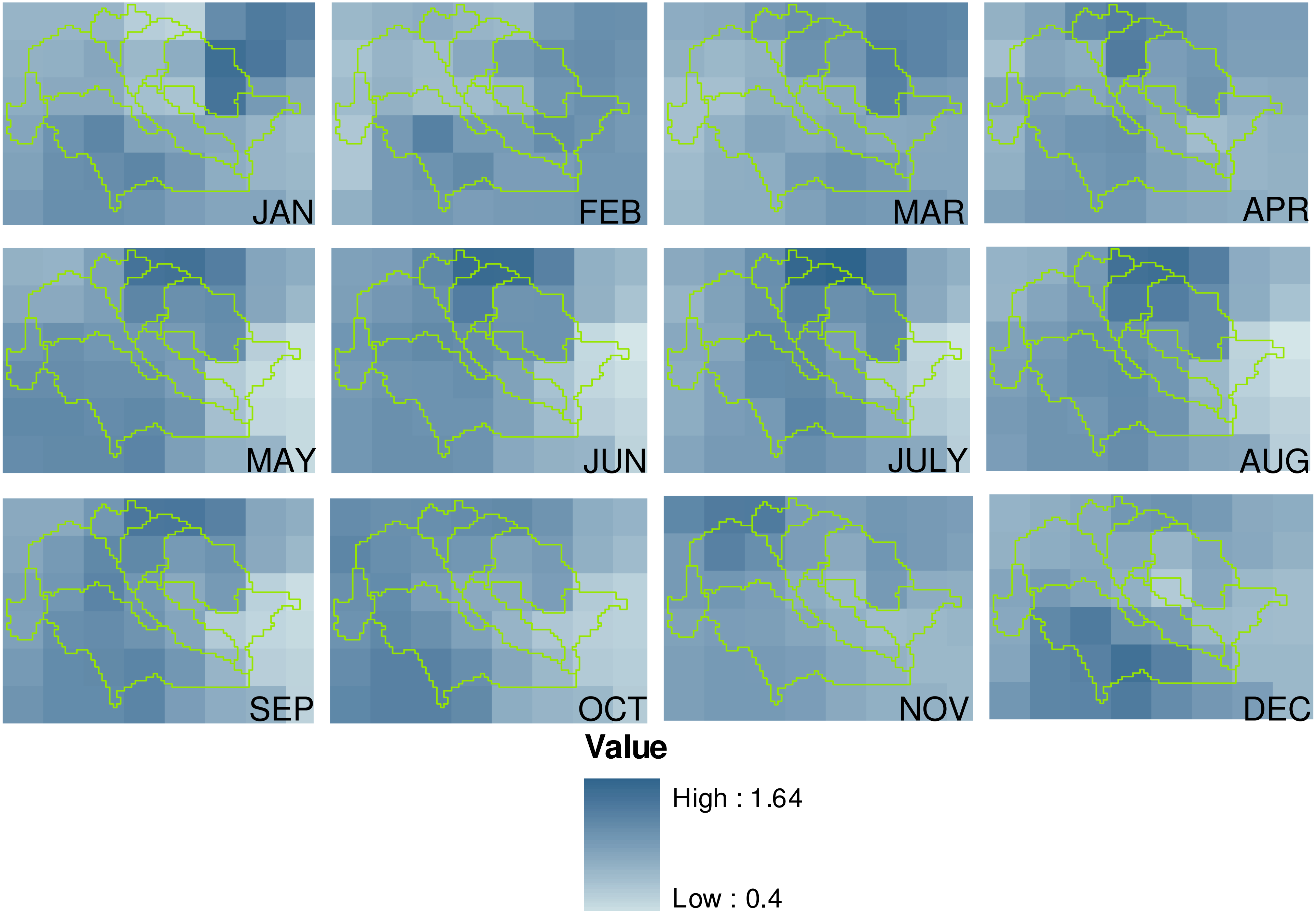




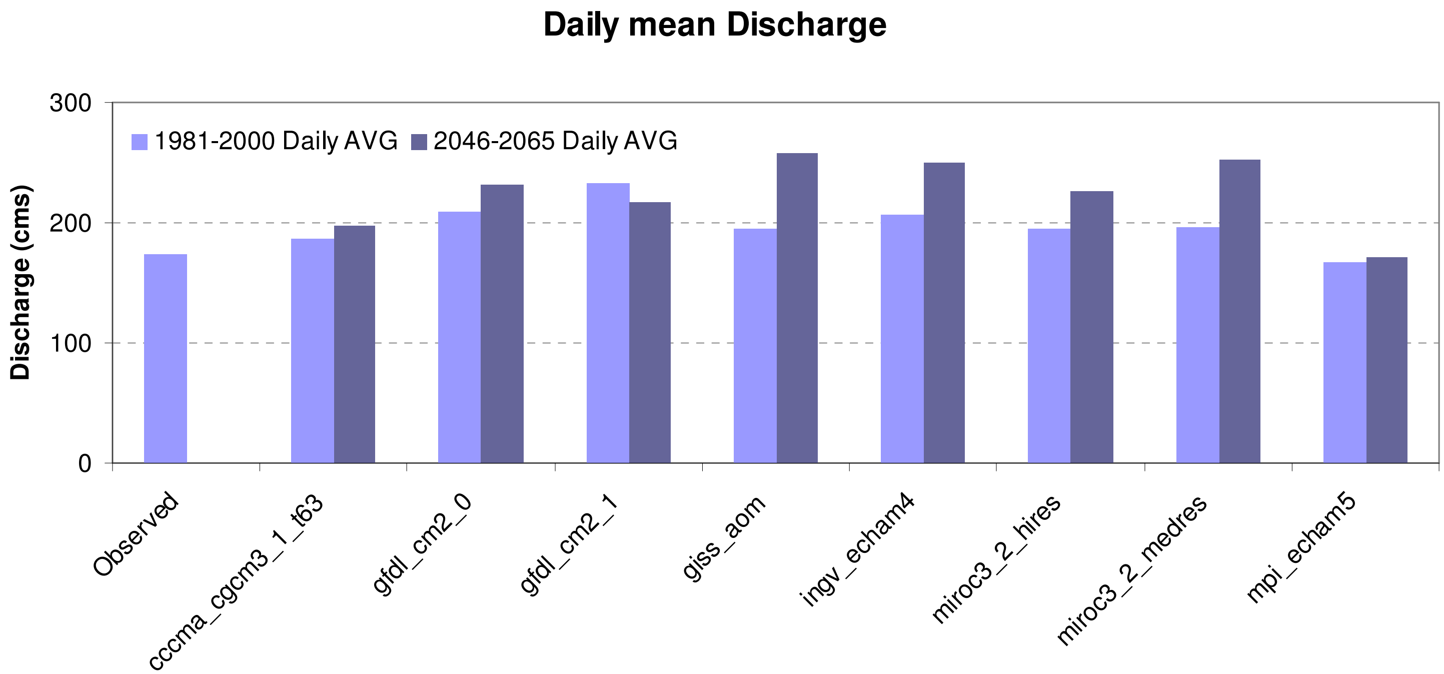
GSMaP: Global Satellite Mapping of Precipitation

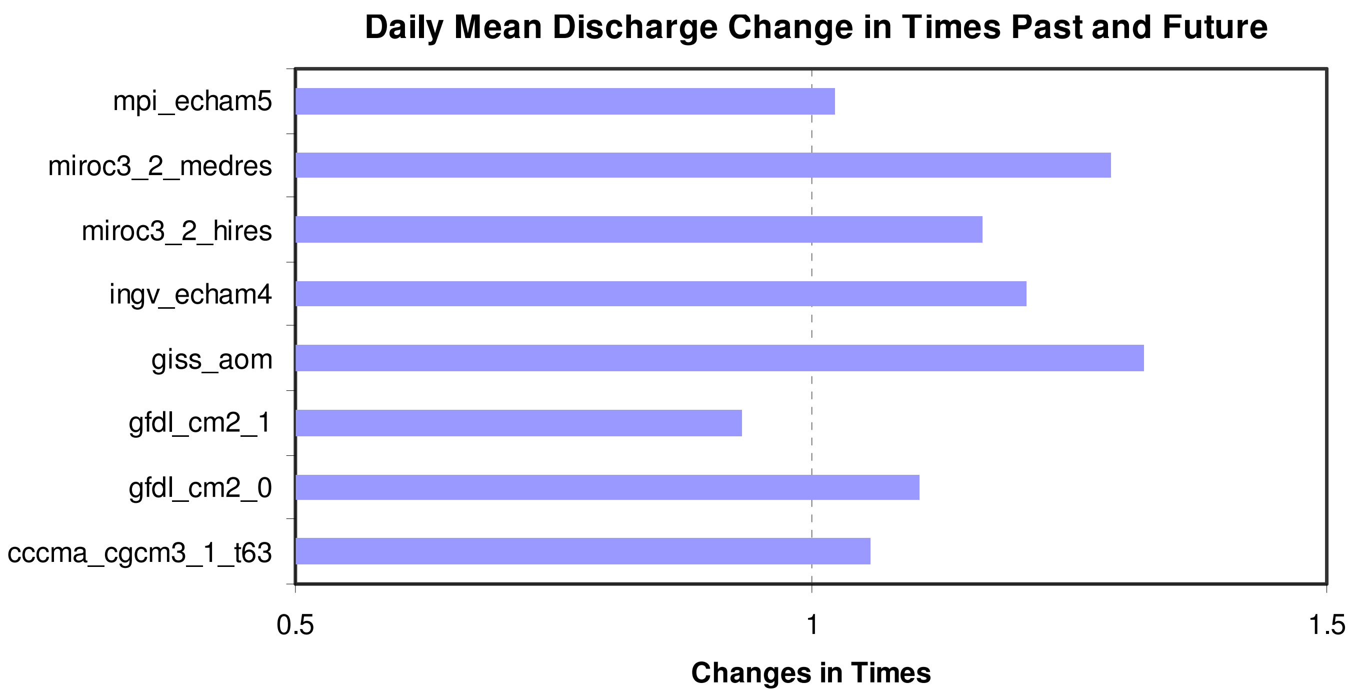
Dataset	GSMap_MVK+	Observed
Grid resolution	0.1 degree lat/lon	point Rain gauge
Temporal resolution	1 hour	1 day
Domain	Global(60N–60S)	Basin scale
Available period	Monthly(2003–2008) Daily(2003–2008) Hourly(2003–2008)	Daily(1981–2008)

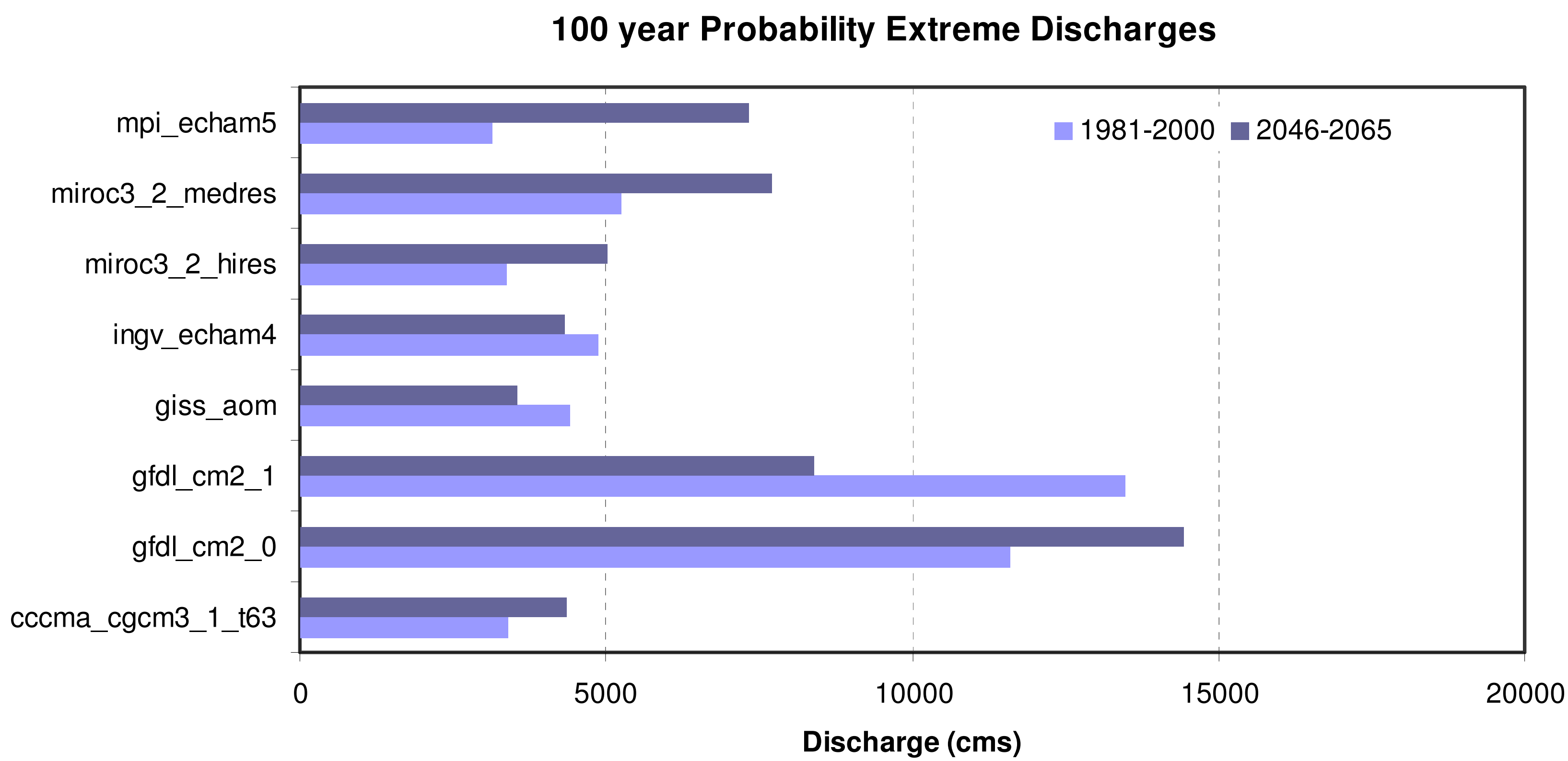




Spatial Distribution Pattern of each month from GSMaP Corrected Rainfall

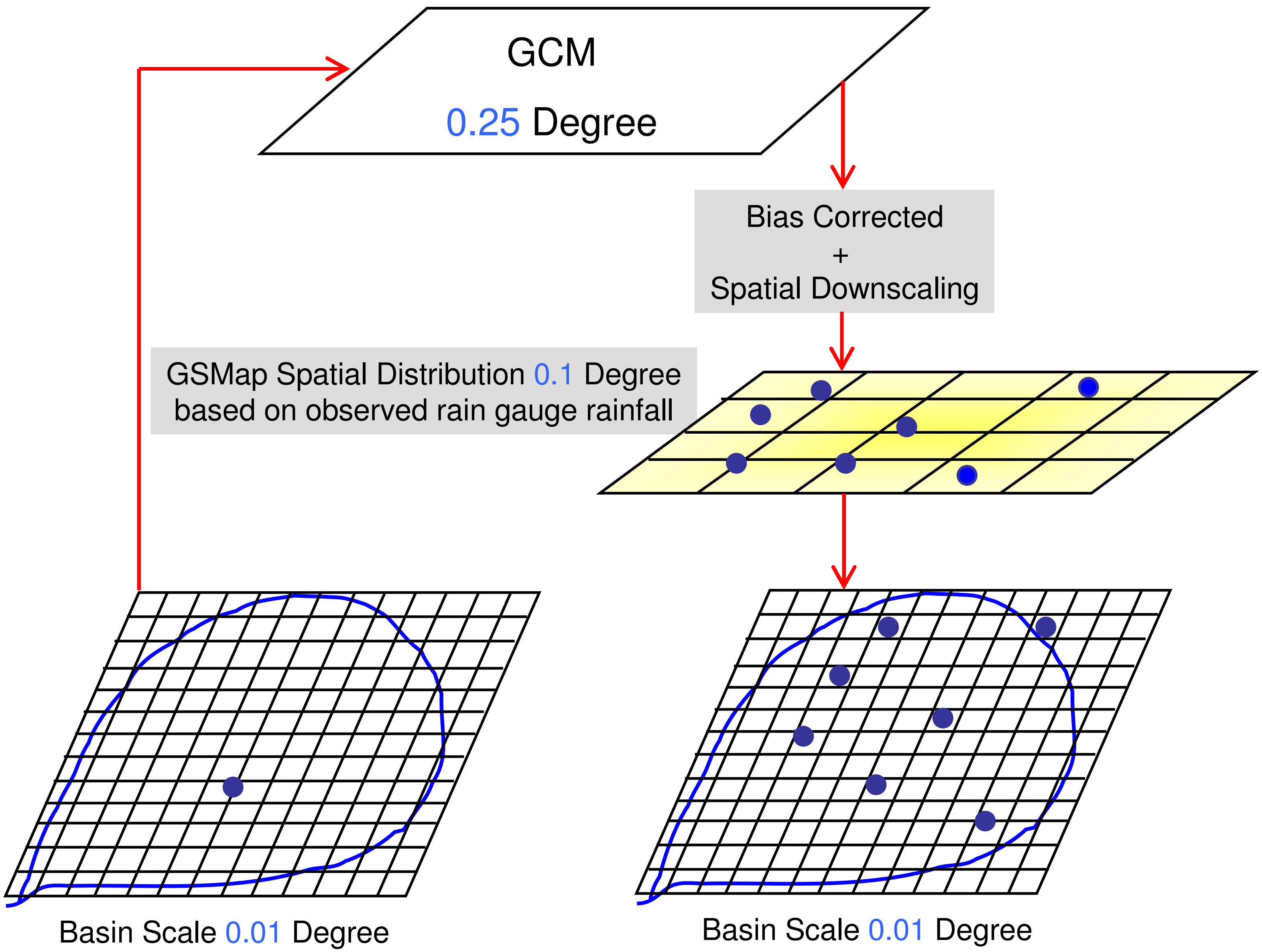

Daily mean Discharge
300
200
100
0
Discharge (cms)
1981-2000 Daily AVG
2046-2065 Daily AVG
Observed
cccma_cgcm3_1_t63
gfdl_cm2_0
gfdl_cm2_1
giss_aom
ingv_echam4
miroc3_2_hires
miroc3_2_medres
mpi_echam5


Daily Mean Discharge Change in Times Past and Future
mpi_echam5
miroc3_2_medres
miroc3_2_hires
ingv_echam4
giss_aom
gfdl_cm2_1
gfdl_cm2_0
cccma_cgcm3_1_t63
0.5
1
1.5
Changes in Times

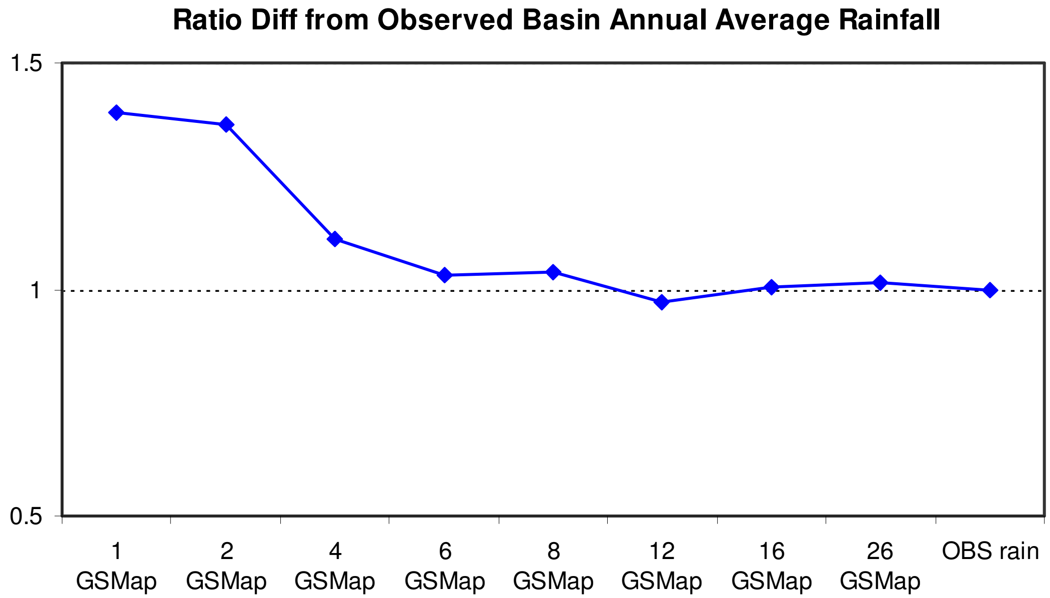


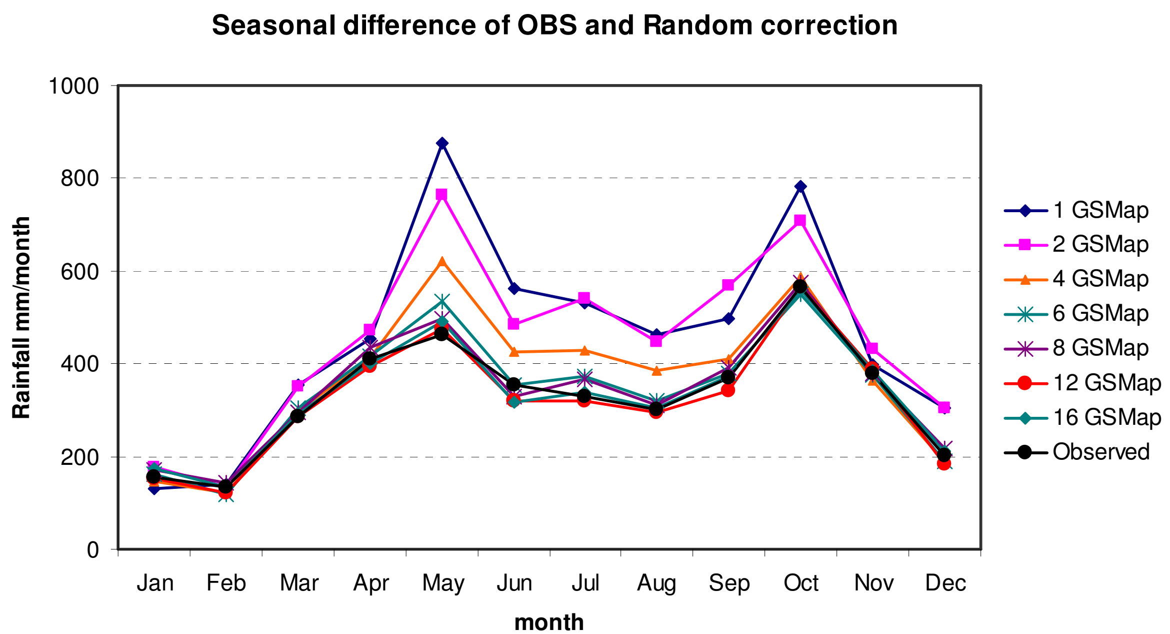
100 year Probability Extreme Discharges
mpi_echam5
miroc3_2_medres
miroc3_2_hires
ingv_echam4
giss_aom
gfdl_cm2_1
gfdl_cm2_0
cccma_cgcm3_1_t63
1981-2000
2046-2065
0
5000
10000
15000
20000
Discharge (cms)

New Method for GSMap Spatial Distribution Map



Checking Sensitivity of Numbers of Rain gauges





Conclusion & Discussion

- Bias-correction method was capable of correction large bias of GCM rainfall of annual maximum rainfall, number of no rain days and seasonal cycle pattern.

- Downscaling using seasonal spatial rainfall-map produced from GSMaP products are applicable to basin with poor gauges.

- From sensitivity of number of raingauges, random selection of 6 gauges or 8 gauges based monthly correction of spatial distribution map show annual mean rainfall are acceptable.

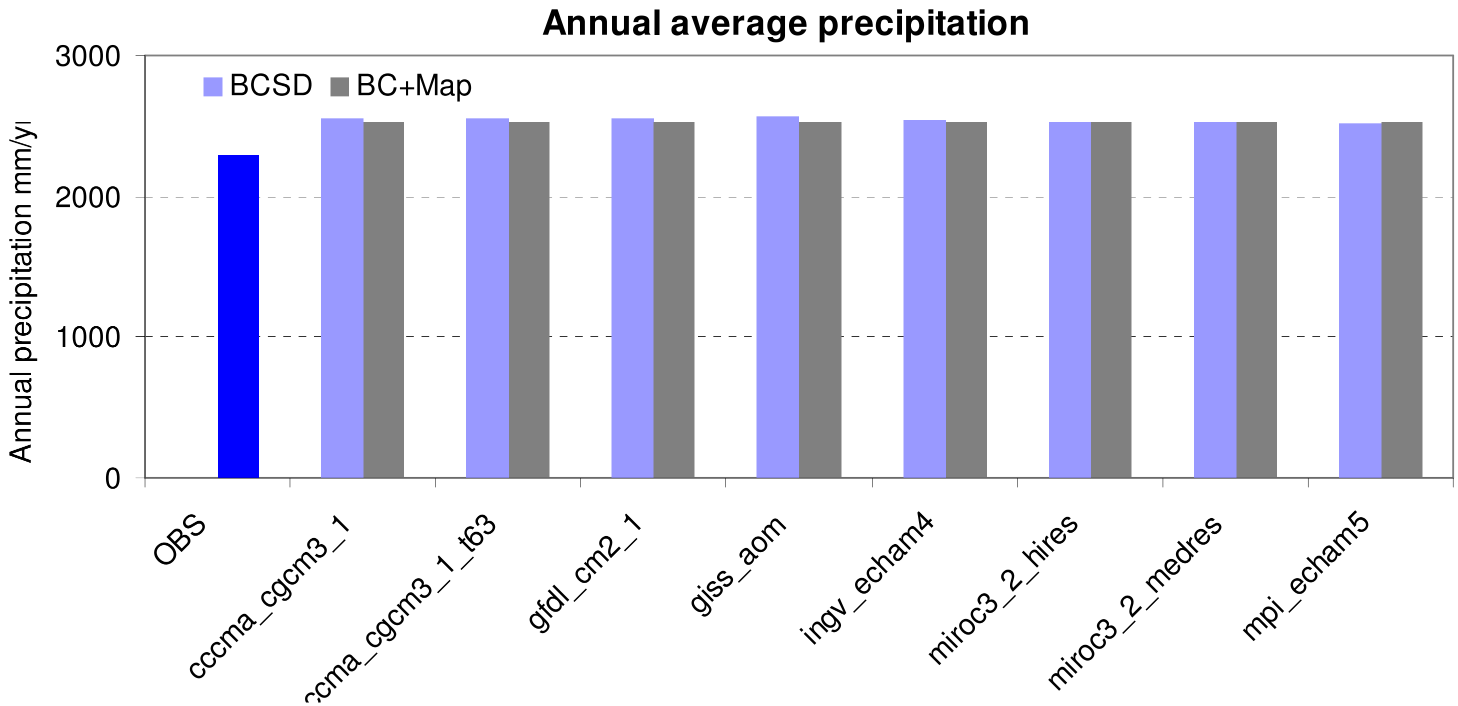
- Climate change impacts on the catchment-scale hydrologic system can assess the potential effects of changes to cope with a changing water balance under future scenarios and to support the sound decision for Integrated Water Resources Management (IWRM).

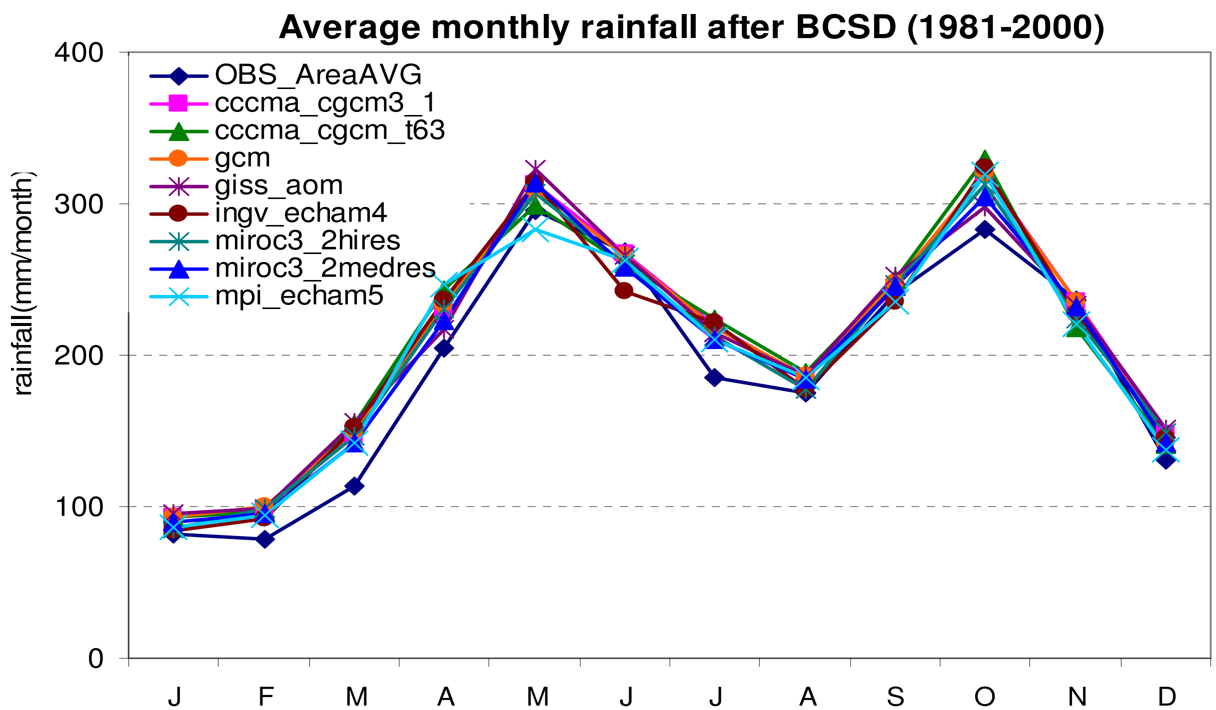
Thanks for your attention !

REEL

Bias Correction Method (Briefly)

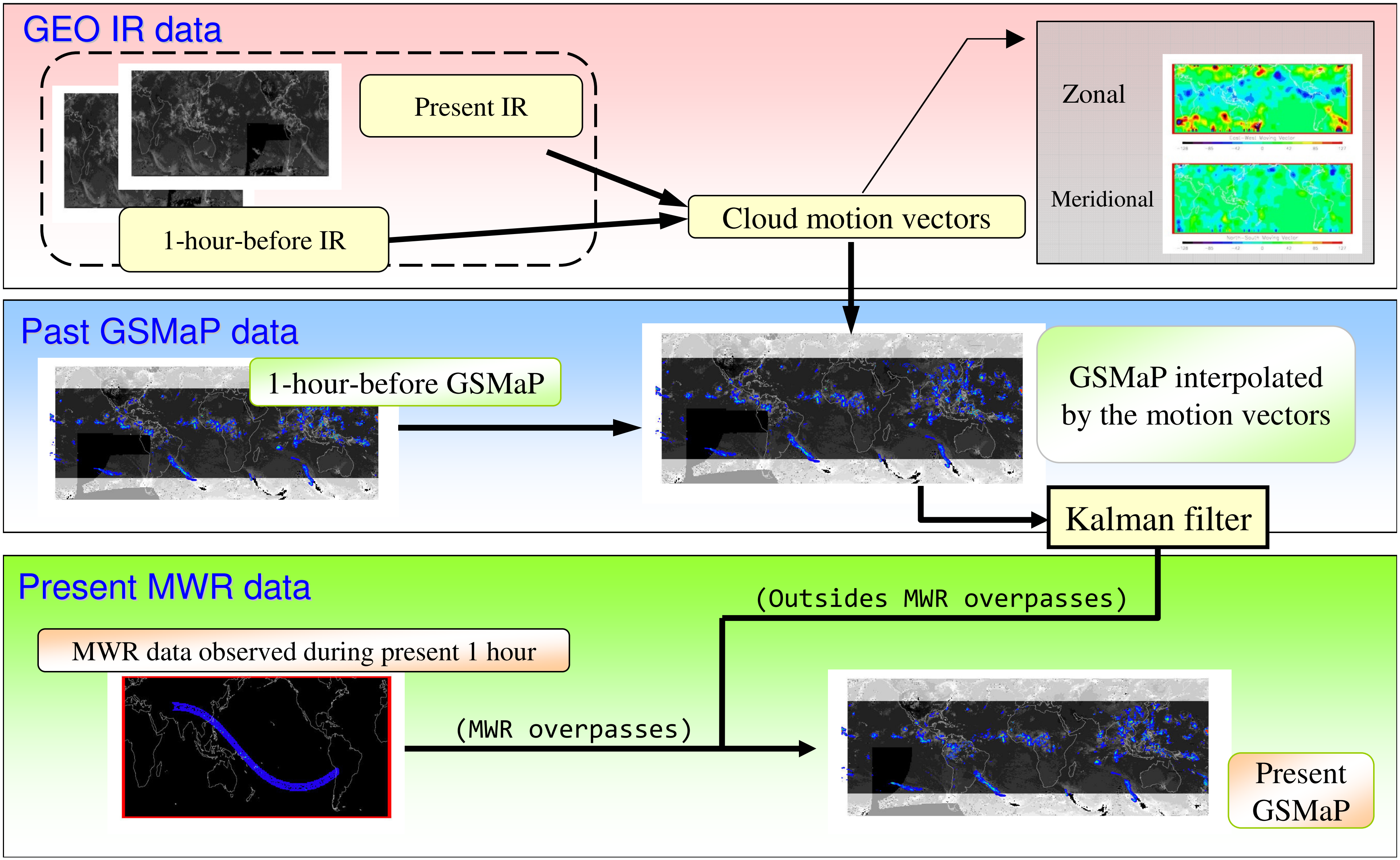
- Daily rainfall from 16 GCMs are corrected.
- Non-Heavy Rainfall
  - Ratio between GCM and Obs. in each month multiplied by GCM daily data.
- Heavy Rainfall
  - By Plotting Position
    - Pattern of Heavy Rainfall is estimated from annual maximum rainfall in 20 years
- No-Rainfall periods
  - By Rank-order statistics


Annual average precipitation
3000
2000
1000
0
BCSD
BC+Map
Annual precipitation mm/yr
OBS
cccma_cgcm3_1
ccma_cgcm3_1_t63
gfdl_cm2_1
giss_aom
ingv_echam4
miroc3_2_hires
miroc3_2_medres
mpi_echam5


Average monthly rainfall after BCSD (1981-2000)
400
300
200
100
0
rainfall(mm/month)
OBS_AreaAVG
cccma_cgcm3_1
cccma_cgcm_t63
gcm
giss_aom
ingv_echam4
miroc3_2hires
miroc3_2medres
mpi_echam5
J
F
M
A
M
J
J
A
S
O
N
D

Flowchart of Blended MWR-IR algorithm (GSMaP_MVK algorithm)

http://sharaku.eorc.jaxa.jp/GSMaP_crest/index.html



Method for GSMap Correction & Spatial Distribution Map

OBS gauged Daily RF 2003-2008 → **IDW (10 km)** → OBS gauged based GSMap Daily RF 2003-2008

GSMap RAW Daily RF 2003-2008

monthly

$$\left[correction\_factor(i,Jan)\right]_{i=1}^{total\_grid} = \frac{\int_{2003}^{2008} OBS\_based\_GSMap(i,Jan)}{\int_{2003}^{2008} GSMap\_raw(i,Jan)}$$

daily

$$\left[corrected\_GS(i,Jan)_{day=1}^{31}\right]_{i=1}^{total\_grid} = \left[correction\_factor(i,Jan)\right]_{i=1}^{total\_grid} * \left[GSMap\_raw(i,Jan)_{day=1}^{31}\right]_{i=1}^{total\_grid}$$

monthly

$$\left[Spatial\_dis(i,Jan)\right]_{i=1}^{total\_grid} = \frac{\int_{2003}^{2008} sum\_corrected\_GS(i,Jan)}{\dfrac{\int_{2003}^{2008} \sum_{i=1}^{total\_grid} sum\_corrected\_GS(i,Jan)}{Total\_grid}}$$

Area Average Monthly Corrected GSMap

monthly

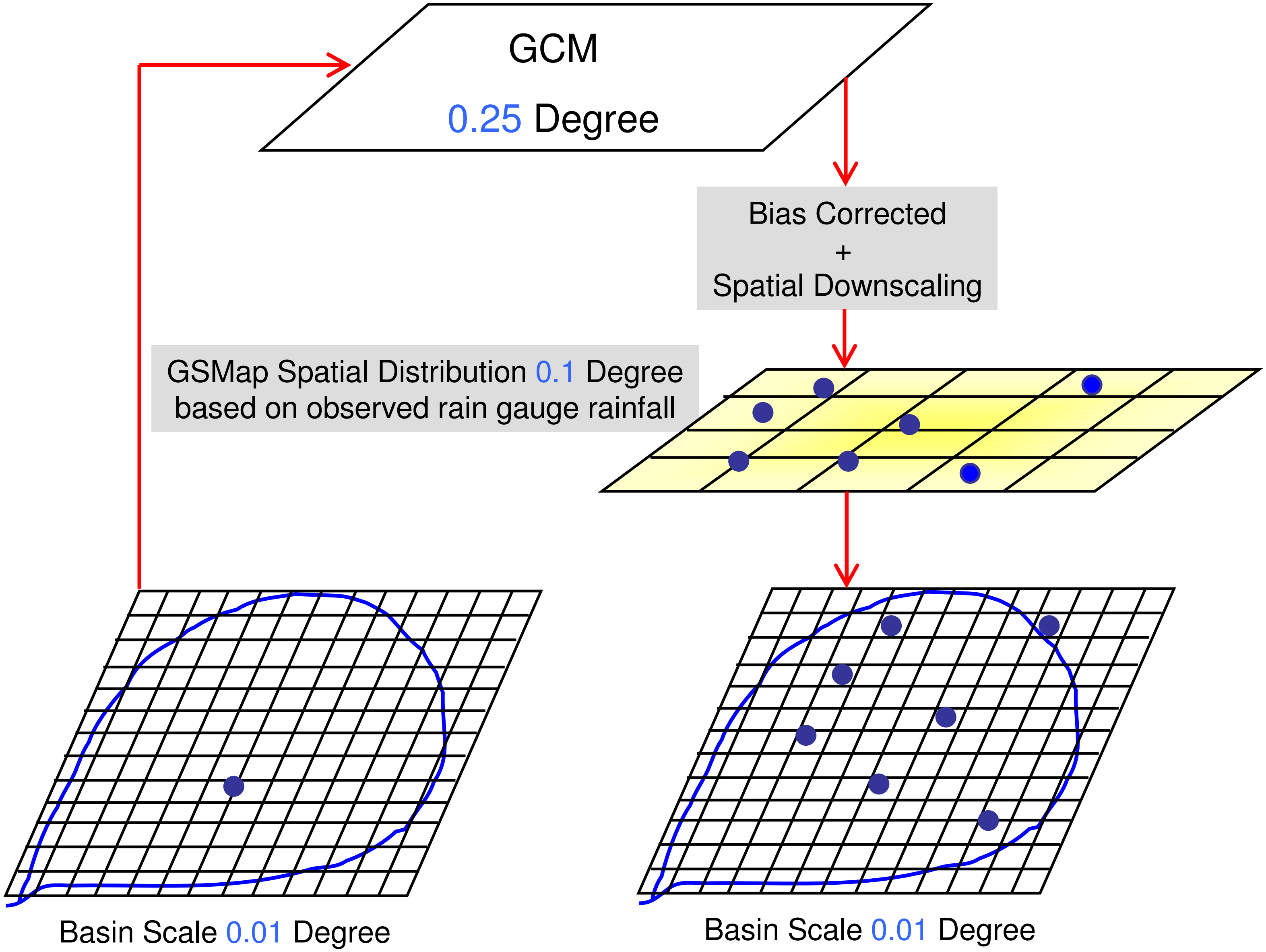
$$\frac{Spatial\_dis_2(Jan)}{Spatial\_dis_1(Jan)} = \frac{\int_{1981}^{2000} \sum_{g=1}^{n} obs\_rain(g,Jan)/n}{\int_{1981}^{2000} \sum_{g=1}^{m} obs\_rain(g,Jan)/m}$$

Validation

n = in-stu rain gauge points in GSMap grid no (2)

m = in-stu rain gauge points in GSMap grid no (1)

New Method for GSMap Spatial Distribution Map



Evaluation of the precipitation over the South Asian summer monsoon domain (60-110E, 0-30N)

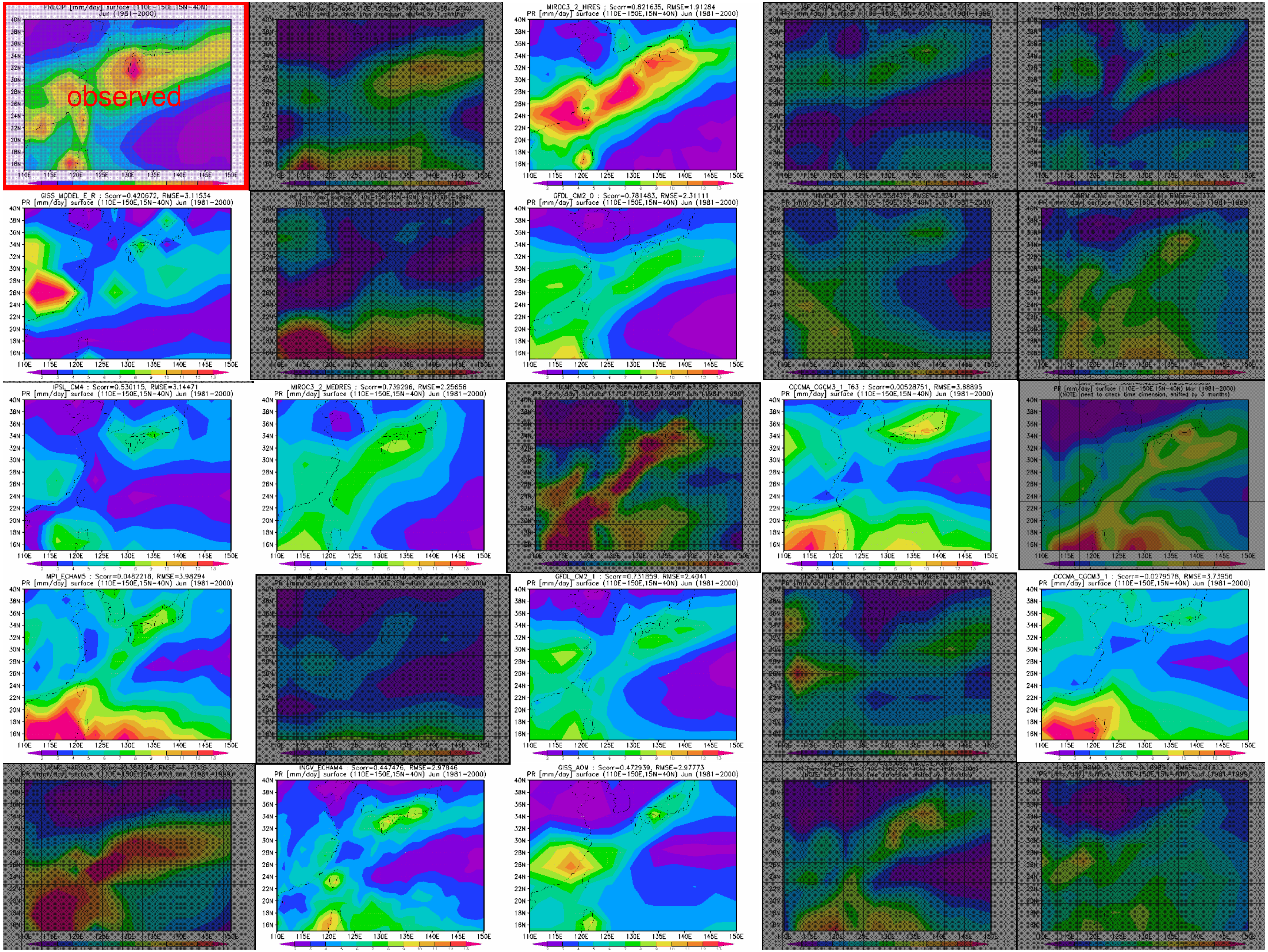
SASM	60--110, 0--30												
Precip	April		May		June		July		August		Sep	Average	
bcc_cm1	0.435363	2.20293	0.351957	3.98466	-0.18979	7.33585	-0.11612	7.69707	0.006347	7.01232		0.013101	6.507475
bccr_bcm2_0	0.822327	1.16383	0.782646	1.82927	0.614945	3.55863	0.560668	3.88737	0.495542	3.63477		0.61345	3.22751
cccma_cgcm3_1	0.710679	1.43027	0.610501	2.43838	0.583323	3.53722	0.489887	4.15787	0.458204	3.98371		0.535479	3.529295
cccma_cgcm3_1_t63	0.633155	1.62093	0.593776	2.513	0.545908	3.64895	0.479107	4.21173	0.427661	4.13408		0.511613	3.62694
cnrm_cm3	0.47961	1.91267	0.45875	2.6902	0.363655	3.98952	0.522781	4.0102	0.454721	3.75038		0.449977	3.610075
csiro_mk3_0	0.681304	1.89885	0.584026	3.18901	0.421825	4.4756	0.602058	4.07465	0.721789	2.96891		0.582425	3.677043
csiro_mk3_5	0.731134	1.78203	0.601754	2.6487	0.335894	4.76901	0.462052	4.52435	0.637283	3.3684		0.509246	3.827615
gfdl_cm2_0	0.80774	1.62894	0.724765	2.37888	0.541752	3.81331	0.722062	3.28271	0.727984	2.86793		0.679141	3.085708
gfdl_cm2_1	0.814813	1.39847	0.759711	1.8663	0.648857	3.22663	0.670102	3.47762	0.679901	3.11751		0.689643	2.922015
giss_aom	0.772134	1.62301	0.648293	2.65074	0.178269	5.19428	0.297611	5.14706	0.497111	3.94056		0.405321	4.23316
giss_model_e_h	0.447221	3.66635	0.542641	4.38294	0.497848	5.58869	0.433207	6.63656	0.408023	5.8409		0.47043	5.612273
giss_model_e_r	0.355913	3.64394	0.301088	4.70783	0.322233	5.48228	0.453387	5.71674	0.484256	4.78768		0.390241	5.173633
iap_fgoals1_0_g	0.797573	1.40983	0.527911	3.08208	0.070555	5.26543	0.103627	5.26839	0.305703	4.1879		0.251949	4.45095
ingv_echam4	0.795484	1.4553	0.746763	1.93977	0.848967	2.26529	0.608655	3.73567	0.651684	3.14852		0.714017	2.772313
inmcm3_0	0.775592	1.36879	0.533247	2.63827	0.460578	4.21037	0.422828	4.86108	0.42993	4.11046		0.461646	3.955045
ipsl_cm4	0.816262	1.58434	0.662895	2.49371	0.179387	5.16682	0.161723	5.90075	0.422998	4.52524		0.356751	4.52163
miroc3_2_hires	0.785238	1.40889	0.721657	2.06697	0.737769	3.02901	0.427264	4.82263	0.324318	4.9501		0.552752	3.717178
miroc3_2_medres	0.84779	1.12375	0.796952	1.90864	0.714404	3.23897	0.364235	5.00753	0.253745	4.87638		0.532334	3.75788
mpi_echam5	0.815629	1.44921	0.741905	2.65412	0.622195	3.6512	0.513517	4.28713	0.529275	3.84724		0.601723	3.609923
mri_cgcm2_3_2a	0.761313	1.53091	0.682407	2.59346	0.435668	4.59874	0.331338	5.27683	0.326953	4.81737		0.444092	4.3216
ncar_ccsm3_0	0.679412	1.54697	0.510291	2.39872	0.467235	3.75278	0.414303	4.39304	0.447615	4.13599		0.459861	3.670133
ncar_pcm1	0.622624	1.61	0.518716	3.10274	0.617724	3.79834	0.334982	5.10899	0.346659	4.65725		0.45452	4.16683
ukmo_hadcm3	0.770506	2.13181	0.708289	2.4777	0.511767	4.10427	0.607112	3.96262	0.593314	3.97023		0.60521	3.628705
ukmo_hadgem1	0.788502	1.97911	0.699569	2.84554	0.522098	4.58143	0.637898	4.81879	0.627638	4.66448		0.621801	4.22756
												0.51711	3.883696

Total model-average

Calculated monthly Scorr and RMSE from May to August for each 23 GCM models, and then obtained the 4 months averages. If a model satisfies both Scorr and RMSE better than total model average, it is counted as a good model for the precipitation over the SASM domain.

SAM: South Asian Monsoon EAM: East Asian Monsoon SEA: Sea Surface

	SAM			EAM			Tibetan H			SEA	Total
	Pr.	OLR.	Pres.	Pr.	OLR.	Pres.	Pres.1	Pres.2	Ta	sst	Score
gfdl_cm2_1	1	1	1	1	1	1	0	1	1	1	9
cccma_cgcm3_1	1	1	1	−1	1	1	1	1	1	1	8
cccma_cgcm3_1_t63	0	1	1	0	1	1	1	1	1	1	8
gfdl_cm2_0	1	1	1	1	1	1	0	1	0	1	8
miroc3_2_medres	1	1	1	1	1	0	0	1	0	1	7
mpi_echam5	1	1	1	−1	1	0	1	1	1	1	7
ingv_echam4	1	1	0	1	1	0	0	0	1	1	6
miroc3_2_hires	1	0	1	1	0	0	1	1	1	0	6
giss_aom	−1	1	1	1	0	1	0	1	0	1	5
csiro_mk3_0	1	1	1	1	−1	0	1	0	1	−1	4
ukmo_hadgem1	0	0	1	0	1	1	1	1	−1	0	4
ukmo_hadcm3	1	1	0	0	−1	1	1	1	1	−1	4
cnrm_cm3	0	0	−1	0	1	1	1	1	0	−1	2
ncar_ccsm3_0	0	0	0	−1	1	−1	1	0	1	1	2
bccr_bcm2_0	1	1	0	0	0	1	0	0	−1	−1	1
mri_cgcm2_3_2a	−1	−1	−1	1	1	0	0	0	1	1	1
csiro_mk3_5	0	0	0	1	−1	0	0	−1	0	0	−1
ncar_pcm1	−1	0	1	−1	−1	−1	1	1	0	−1	−2
ipsl_cm4	−1	−1	1	−1	0	0	−1	0	−1	1	−3
iap_fgoals1_0_g	−1	−1	−1	−1	−1	0	0	1	0	−1	−5
inmcm3_0	−1	−1	1	−1	0	−1	0	−1	−1	−1	−5
giss_model_e_h	−1	−1	−1	0	−1	0	−1	−1	0	0	−6
giss_model_e_r	−1	−1	0	−1	−1	0	−1	−1	0	0	−6
bcc_cm1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−10


PRECIP [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
observed
PR [mm/day] surface (110E-150E,15N-40N) May (1981-2000) (NOTE: need to check time dimension, shifted by 1 months)
MIROC3_2_HIRES : Scorr=0.821635, RMSE=1.91284 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
IAP_FGOALS1_0_G : Scorr=0.334407, RMSE=3.3203 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-1999)
PR [mm/day] surface (110E-150E,15N-40N) Feb (1981-1999) (NOTE: need to check time dimension, shifted by 4 months)
GISS_MODEL_E_R : Scorr=0.420672, RMSE=3.11534 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
PR [mm/day] surface (110E-150E,15N-40N) Mar (1981-1999) (NOTE: need to check time dimension, shifted by 3 months)
GFDL_CM2_0 : Scorr=0.781483, RMSE=2.31111 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
INMCM3_0 : Scorr=0.338437, RMSE=2.9341 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
CNRM_CM3 : Scorr=0.32911, RMSE=3.0372 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-1999)
IPSL_CM4 : Scorr=0.530115, RMSE=3.14471 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
MIROC3_2_MEDRES : Scorr=0.739296, RMSE=2.25656 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
UKMO_HADGEM1 : Scorr=0.48184, RMSE=3.62298 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-1999)
CCCMA_CGCM3_1_T63 : Scorr=0.00528751, RMSE=3.68895 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
PR [mm/day] surface (110E-150E,15N-40N) Mar (1981-2000) (NOTE: need to check time dimension, shifted by 3 months)
MPI_ECHAM5 : Scorr=0.0482218, RMSE=3.98294 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
MIUB_ECHO_G PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
GFDL_CM2_1 : Scorr=0.731859, RMSE=2.4041 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
GISS_MODEL_E_H : Scorr=0.290159, RMSE=3.01002 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-1999)
CCCMA_CGCM3_1 : Scorr=-0.0279578, RMSE=3.73956 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
UKMO_HADCM3 : Scorr=0.383148, RMSE=4.17316 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-1999)
INGV_ECHAM4 : Scorr=0.447476, RMSE=2.97846 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
GISS_AOM : Scorr=0.472939, RMSE=2.97773 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-2000)
PR [mm/day] surface (110E-150E,15N-40N) Mar (1981-2000) (NOTE: need to check time dimension, shifted by 3 months)
BCCR_BCM2_0 : Scorr=0.189851, RMSE=3.21313 PR [mm/day] surface (110E-150E,15N-40N) Jun (1981-1999)

Bias Correction Method (Briefly)

- **Daily rainfall from 16 GCMs are corrected.**
- **Non-Heavy Rainfall**
  - **Ratio between GCM and Obs. in each month multiplied by GCM daily data.**
- **Heavy Rainfall**
  - **By Plotting Position**
    - **Pattern of Heavy Rainfall is estimated from annual maximum rainfall in 20 years**
- **No-Rainfall periods**
  - **By Rank-order statistics**