

2013 GEOSS Joint Asia-Africa Water Cycle Symposium

Climate Change Impact Assessment on Water Resources in the Asia-Pacific Regions

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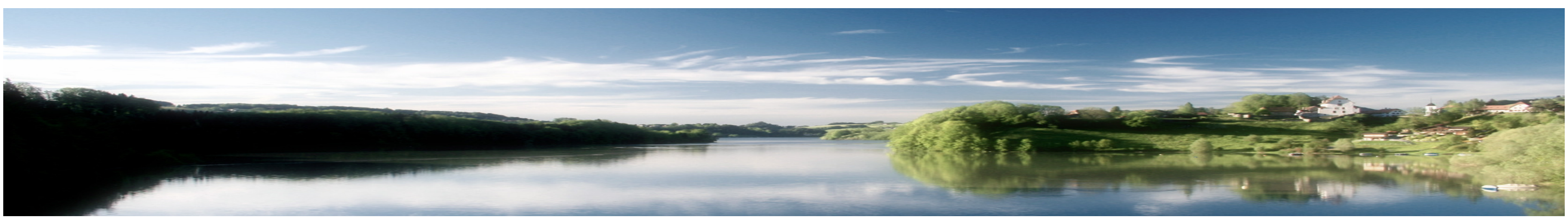
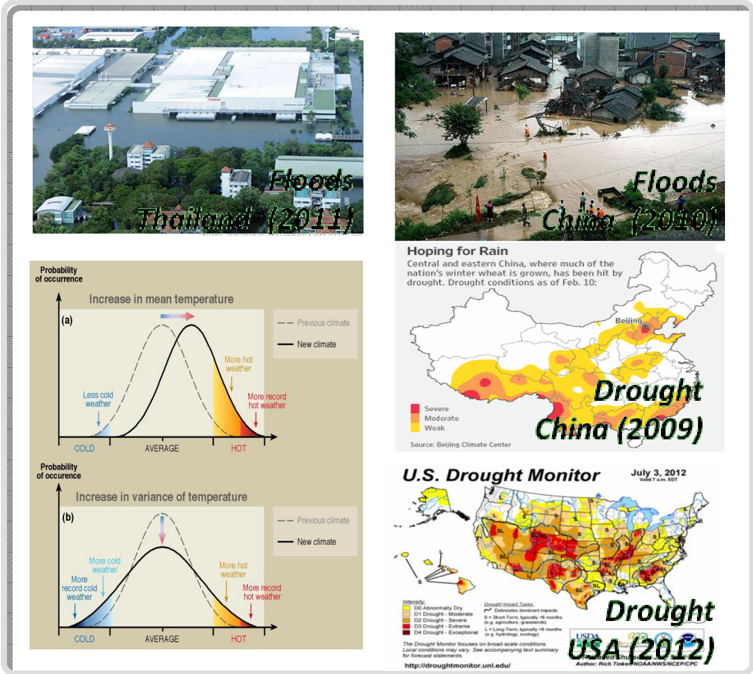


Backgrounds of this study

Motivations of this study

- **Asia monsoon plays an important role on global water cycle**
  - **Provides substantial rainfall and water resources**
  - **Provides many benefits, but also causes serious water-related disasters**
- **Various reasons for the disasters, but the current climate change impacts make much difficult to manage them**



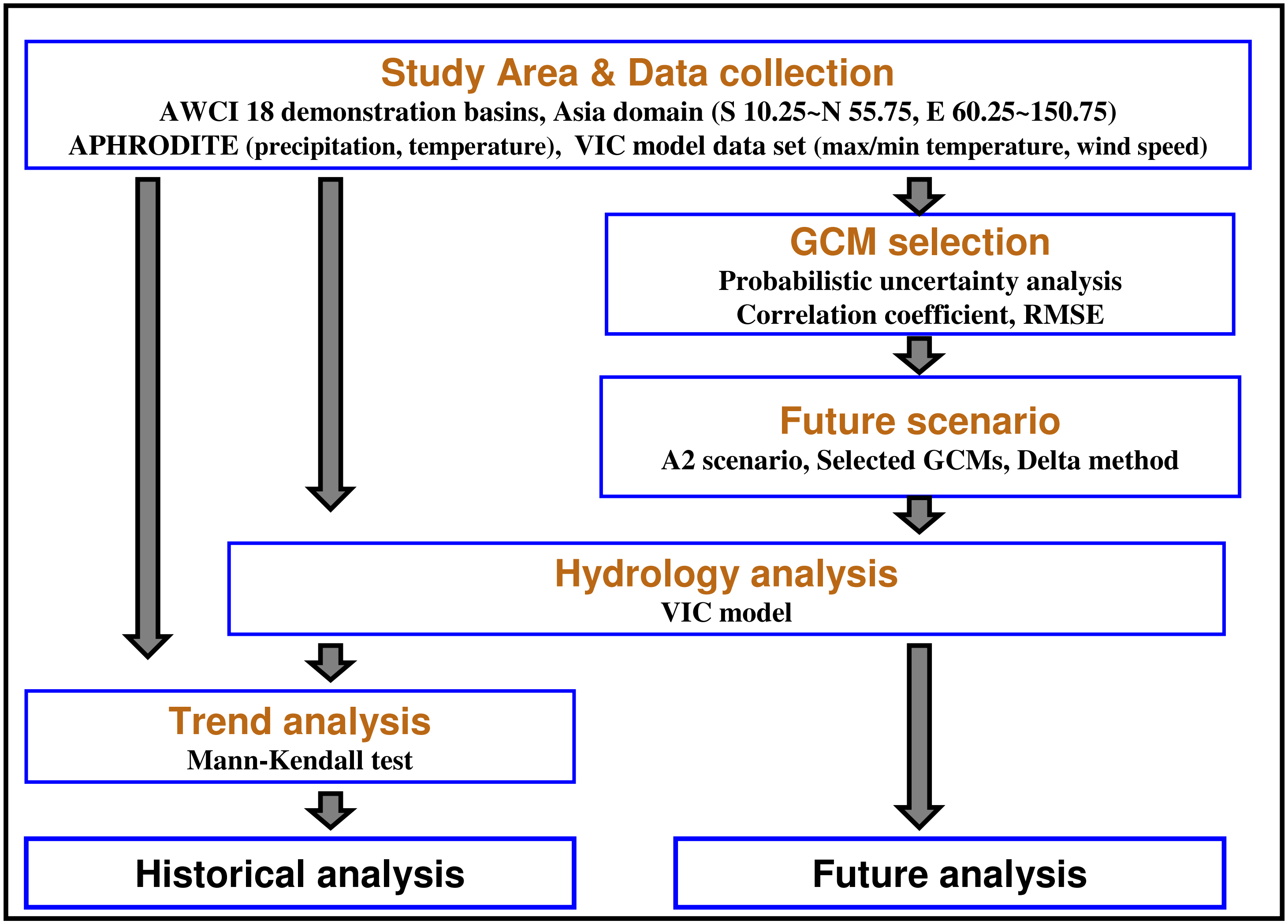
Source: Google image(http://www.google.com/)

The objectives

- **To evaluate the climate change impact assessments on water resources over the Asia-pacific regions joining GEOSS/AWCI**
- **To promote the capacity building for climate change impact assessment technology**

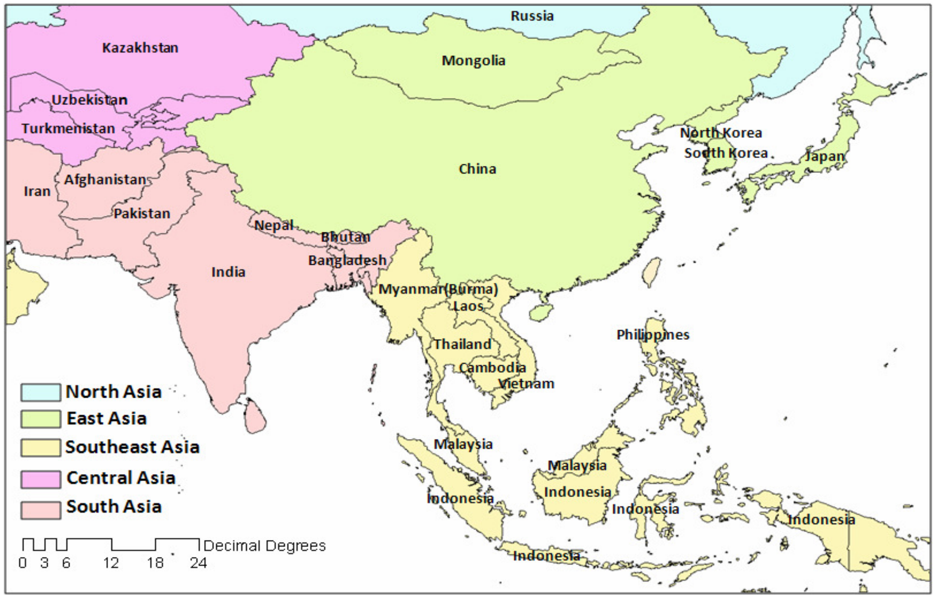
Approaching method

Procedure of this study



Study area

- Boundary : S 10.25~N 55.75, E 60.25~150.75
- Spatial resolution : 1/2° (About 50km)
- 23 countries in East Asia, Southeast Asia, South Asia, Central Asia, North Asia
- 18 AWCI demonstration basins

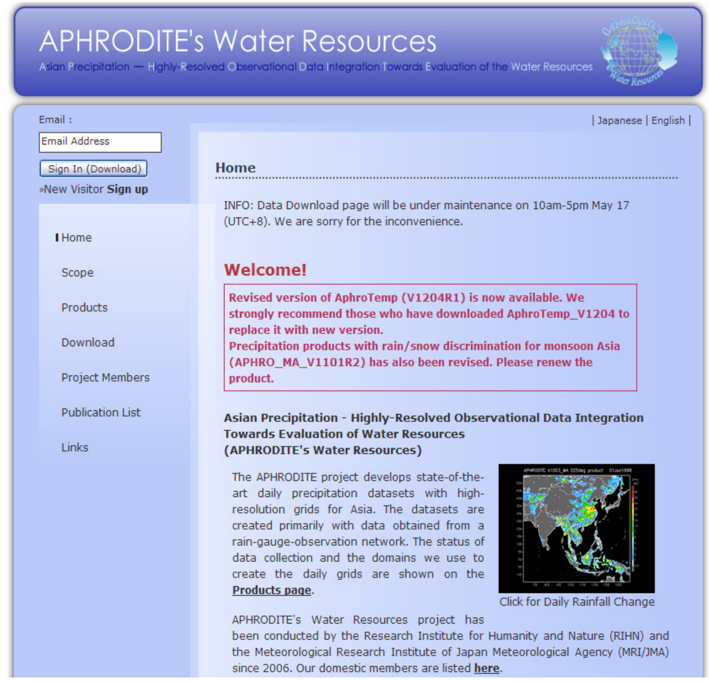


<Domain>

<AWCI 18 demonstration basins>

Meteorological data

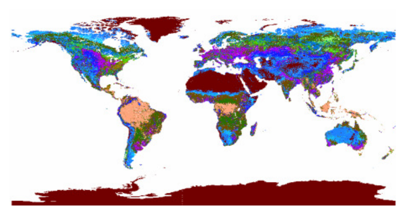
- Precipitation data
  - APHRODITE
  - Daily precipitation, 0.5 ×0.5°
- Climate data
  - University of Washington
  - Daily max & min temperature, mean wind speed
  - 0.5 ×0.5°

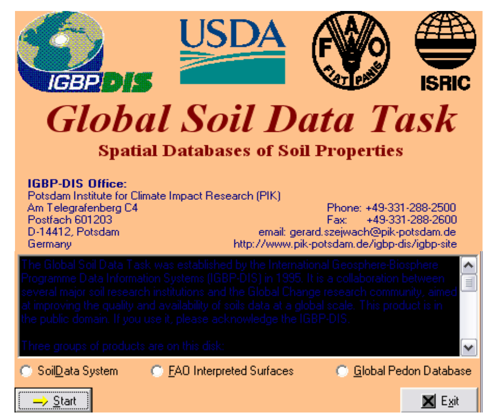


Source : http://www.chikyu.ac.jp/precip/

Geomorphological data

- DEM
  - United States Geological Survey (USGS)
  - Resolution : 30″×30″
- Land use
  - University of Maryland (UMD)
  - Resolution : 1km×1km
- Soil properties
  - Food Agriculture Organization (FAO)
  - Resolution : 5′×5′

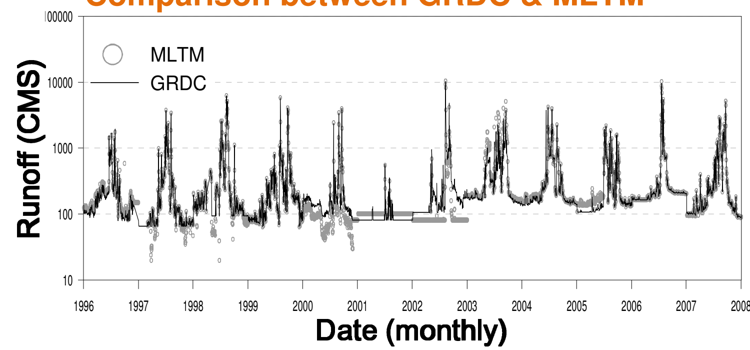


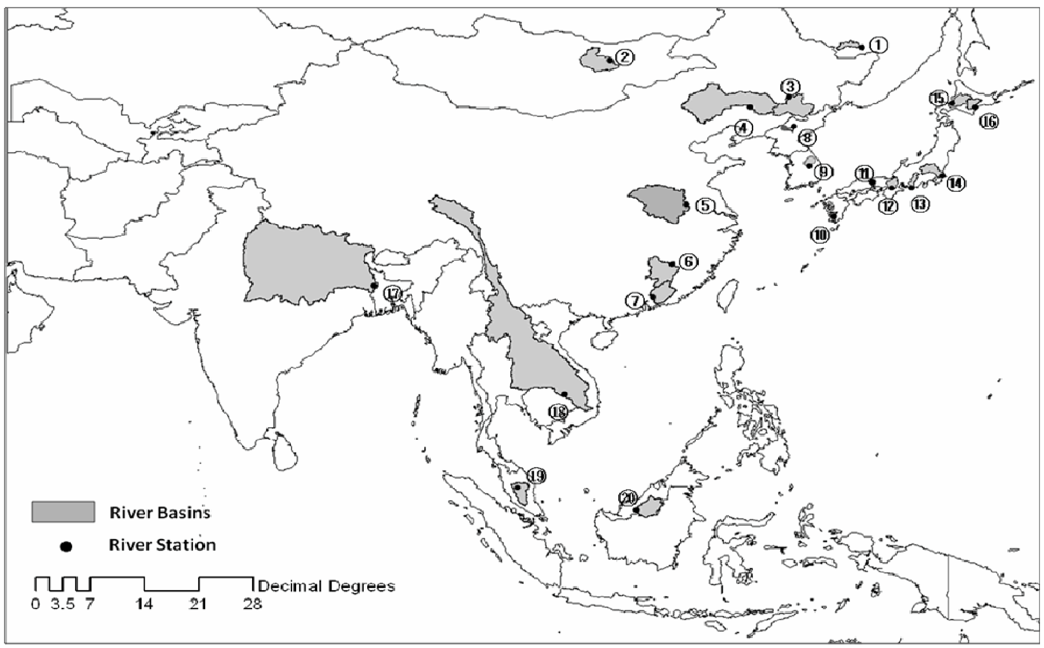


Streamflow data

- Source : GRDC (Global Runoff Data Center)
- Time interval : Monthly data
- Data Period : 20 years (1984~2004)
- Number of selected basins : 20

Comparison between GRDC & MLTM



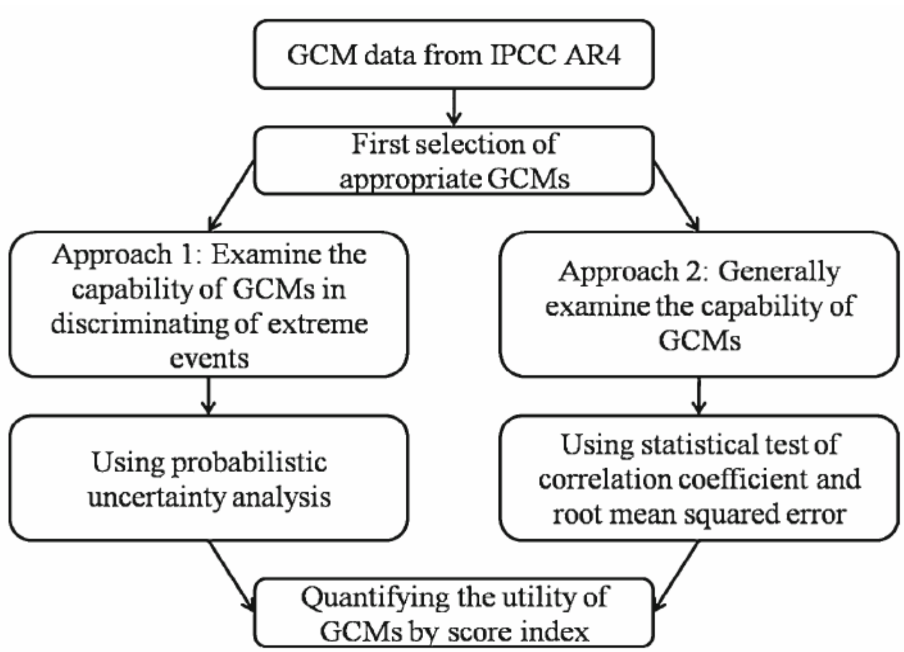


Source : http://www.bafg.de/GRDC/EN/Home/

Climate change scenario

➢ GCM Selection

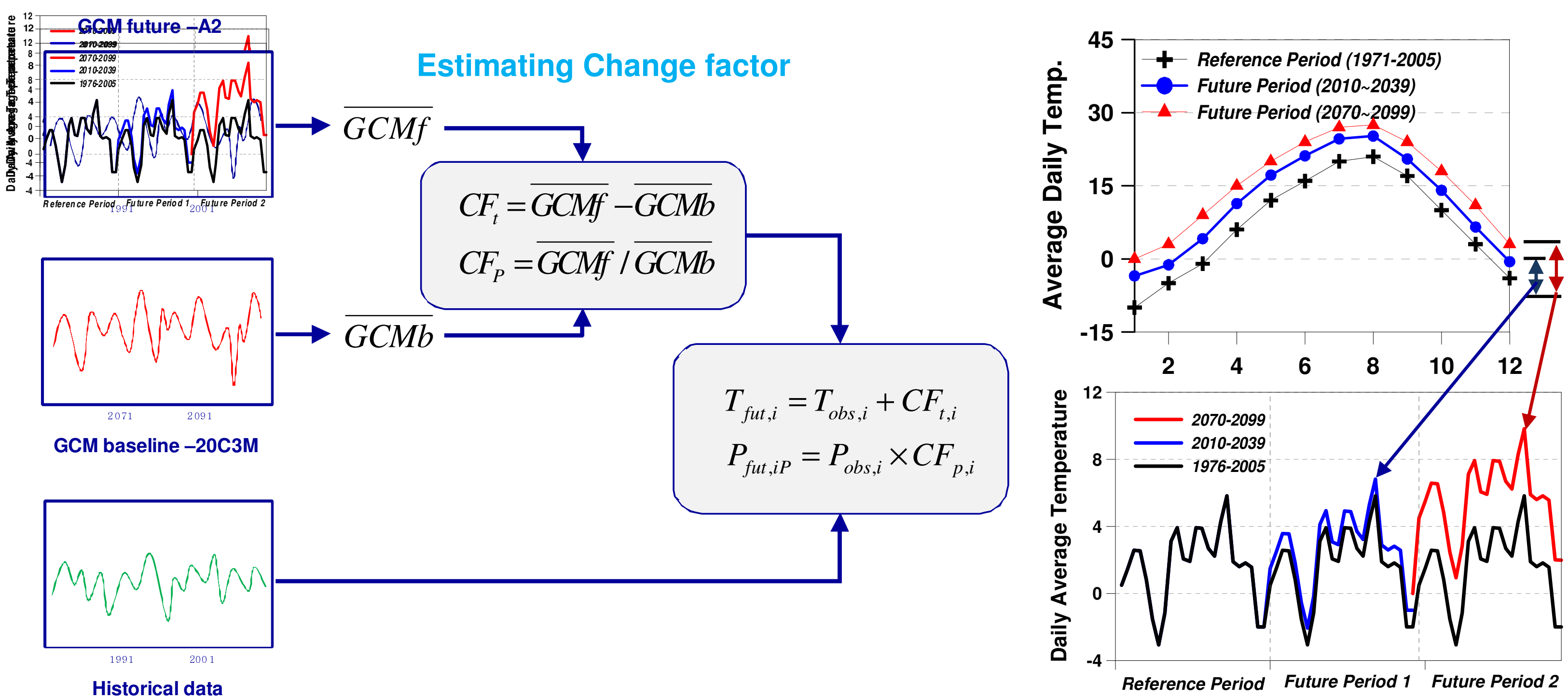
- To compare the effectiveness of each GCM for their future application in Asian region
- Use probabilistic screening methodology and statistical tests of CC & RMSE
- GCM : CGCM3_T47 (CCCMA), CGCM2_3_2 (MRI), CM4 (IPSL)



Source : Le and Bae (2013) Water Resource Management

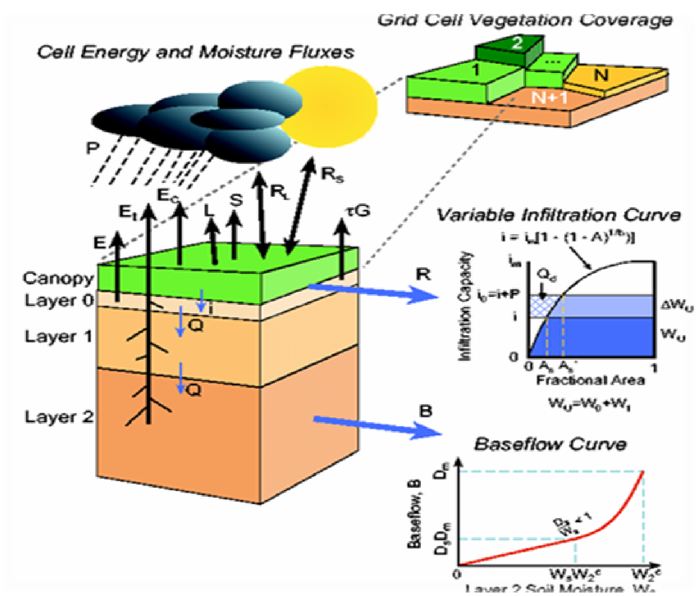
No.	Model (agency: version)	Overall normalized score	Remarks
1	MPIM: ECHAM5	0.82	-
2	CSIRO: MK3.0	0.47	-
3	GFDL: CM2_1	0.26	-
4	CNRM: CM3	0.73	-
5	MRI: CGCM2_3_2	1.28	2nd
6	UKMO: HADCM3	0.55	-
7	IPSL: CM4	0.97	3rd
8	CCCMA: CGCM3_T47	1.70	1st
9	CONS: ECHO-G	0.94	-

- **Emission scenario : SRES A2 (CO_2, 820ppm, 2100yr)**
- **Downscaling : Delta method (Spatial downscaling : bilinear interpolation)**
  - **Reference period: 1977-2006**
  - **Projection periods: 2020s, 2050s, 2080s**
  - **Minimum, maximum temperature, and precipitation**



Hydrologic model

- The VIC (Variable Infiltration Capacity) model is soil vegetation atmospheric transfer scheme that considers both energy and water balances
- A grid-based macro-scale model that is usually implemented at various spatial scales from 1/8 °to 2°
- Widely used for analyzing the variations of water resources on climate change



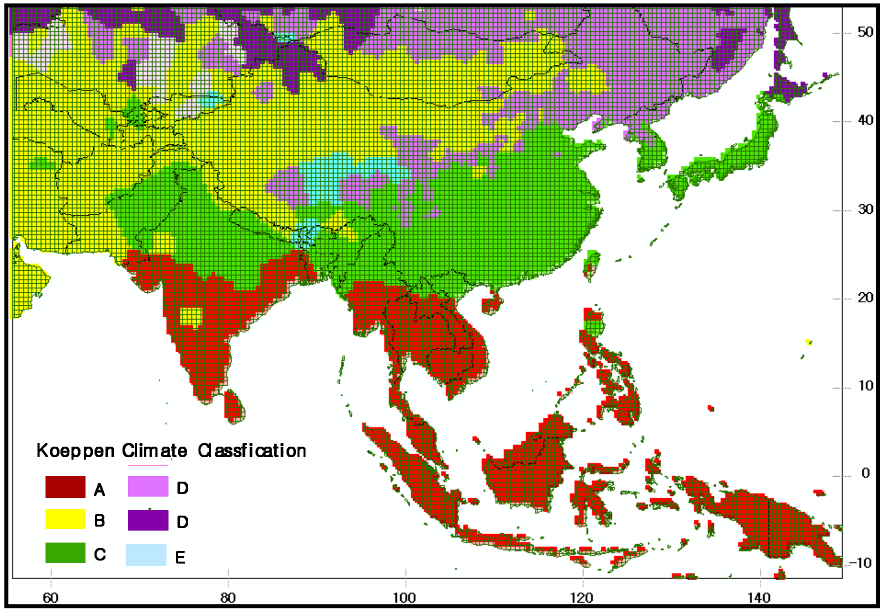
Parameter	Input Data
Basin	DEM
Forcing	Precipitation Maximum Temperature Minimum Temperature Wind Speed
Soil	Soil Properties
Vegetation	Land use

➢ Regionalization method

- **Model calibration at gauged basins and then regionalize the model parameters to ungauged basins in AWCI domain**
- **Climate characteristics defined by the Köppen climate classification is used for regionalization method**
- **Dominant climate types are Arid B (32%), Cold D (27%), Temperate C (21%), Tropical A (18%), Polar E (2%)**

Parameter	Description	Range
b_infilt	Exponent of variable infiltration capacity curve	0.0–10.0
D_s	Fraction of maximum base flow	0.0–1.0
D_{smax}	Maximum velocity of base flow (m/day)	0.0–40.0
W_s	Fraction of maximum soil moisture content of the lower layer	0.0–1.0
d_1, d_2, d_3	Three soil layer thickness (m)	0.05–2.0

Köppen climate zone in Asia regions



➢ **Hydrologic model performances**

- **Evaluate LSM model performance under the assumption that some gauged basins are ungauged basins**
- **The performance are CC : 0.58~0.96, ME : 0.35~0.92, VE : under 26%**

–	Climate Zone	No.	Basin	Statistics			
				CC	ME	RMSE	VE
Cal.	A	⑳	Rajang	0.67	0.36	51.55	−4.84
		⑱	Mekong	0.95	0.91	16.05	−2.25
	B	②	Kerulen	0.79	0.59	1.10	−6.83
	C	⑤	Huai He	0.81	0.63	17.19	−11.50
		⑦	Dong Jiang	0.87	0.66	27.29	−10.79
		⑨	ChungJu Dam	0.96	0.88	31.05	−3.54
		⑬	Tenryu	0.95	0.88	23.97	9.66
	D	⑧	Sangwan	0.88	0.68	31.59	−25.72
	E	⑯	Tokachi	0.73	0.45	32.25	19.01
Ver.	A	⑲	Buluh Kasap	0.58	0.33	63.29	0.46
		⑰	Gangis	0.90	0.76	21.87	17.39
	B	④	Liao He	0.77	0.58	1.61	0.59
	C	⑥	Gan Jian	0.89	0.79	27.79	1.32
		⑩	Sendai	0.96	0.92	41.49	−2.68
		⑪	Yoshino	0.93	0.85	28.10	5.54
		⑫	Yodo	0.86	0.71	30.76	10.60
		⑭	Tone	0.88	0.75	21.58	14.83
	D	③	Songhua Jiang	0.79	0.35	16.31	12.66
	E	⑮	Ishikari	0.64	0.35	46.38	−8.52

Historical data analysis for detecting trends

- Use linear regression analysis & Mann-Kendall's test on the study domain
- Linear regression method were used to characterize the existence of a linear trend
- Mann-Kendall test is a non-parametric test for detecting trends in time series data

$$S = \sum_{i=1}^{n-1} \sum_{k=i+1}^{n} \operatorname{sgn}(x_k - x_i)$$

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} e_i(e_i - 1)(2e_i + 5)}{18}$$

$$Z_c = \frac{S-1}{\sqrt{\operatorname{var}(S)}} \quad S > 0$$

$$Z_c = 0 \quad S = 0$$

$$Z_c = \frac{S+1}{\sqrt{\operatorname{var}(S)}} \quad S > 0$$

- If $-Z_{1-\alpha/2} \le Z_c \le Z_{1-\alpha/2}$, Z_c is not statistically significant or no significant trend.

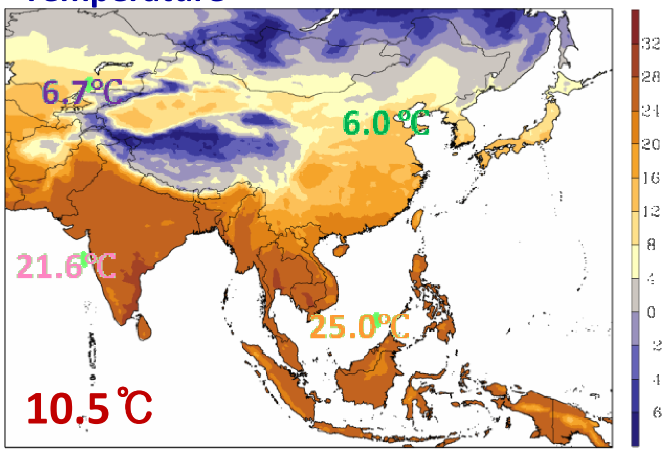
- Indices of temperature, precipitation, runoff
  - Annual & seasonal average temperature, annual & seasonal precipitation, annual & seasonal runoff

Results and Analysis

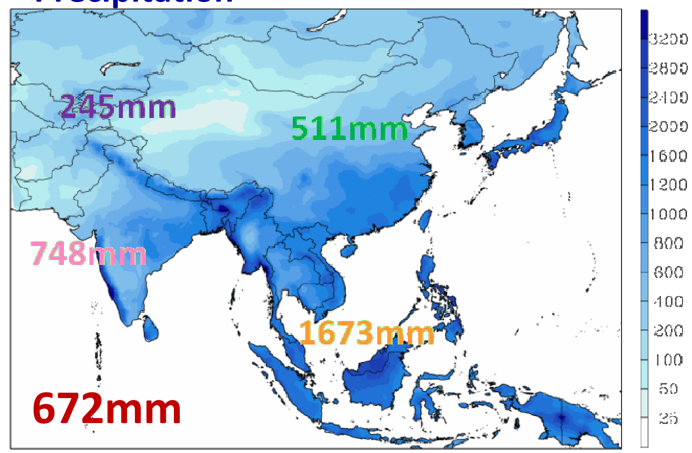
Analysis of historical climate and hydrology

➢ **Annual average temperature, precipitation and runoff over the Asian regions**

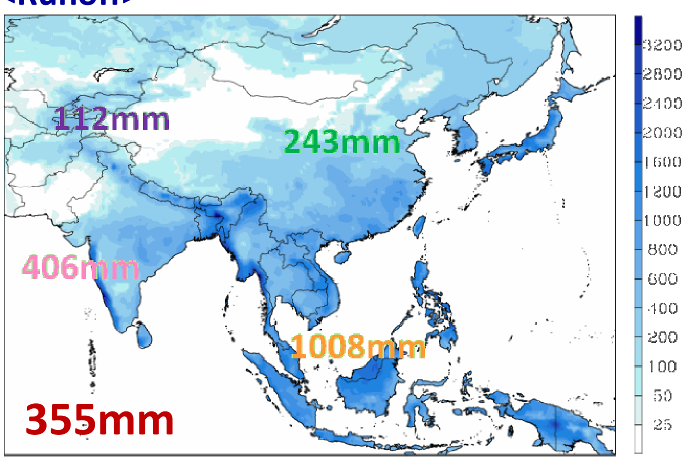
<Temperature>



<Precipitation>



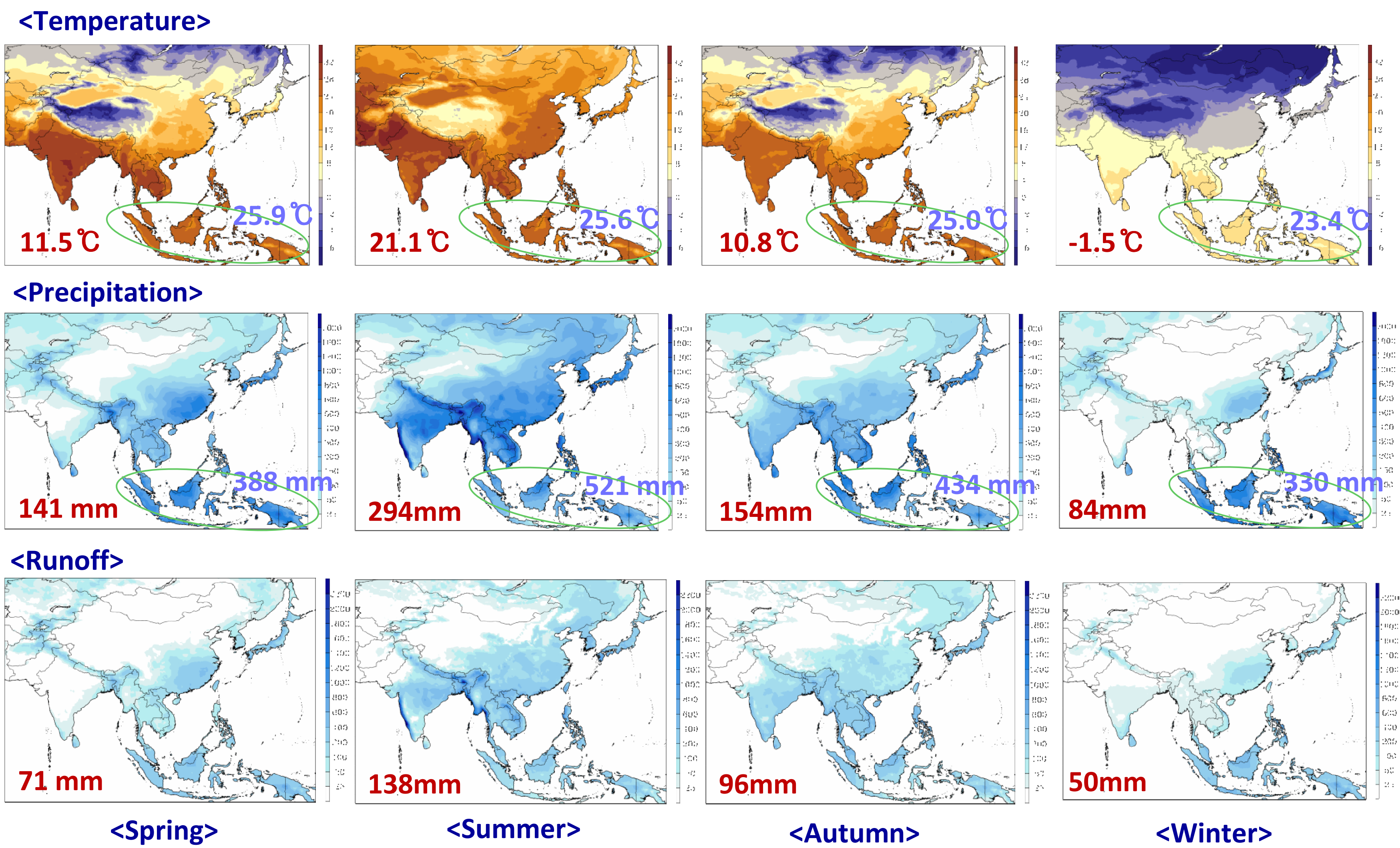
<Runoff>



Basin	Temp.(℃)	Pre.(mm)	Run.(mm)	Ratio(%)
Asia	10.5	672	354	52.7
East Asia	6.0	511	243	47.6
Southeast Asia	25.0	1673	1008	60.3
South Asia	21.6	748	405	54.1
Central Asia	6.7	245	111	45.3
North Asia	-1.9	431	180	41.8

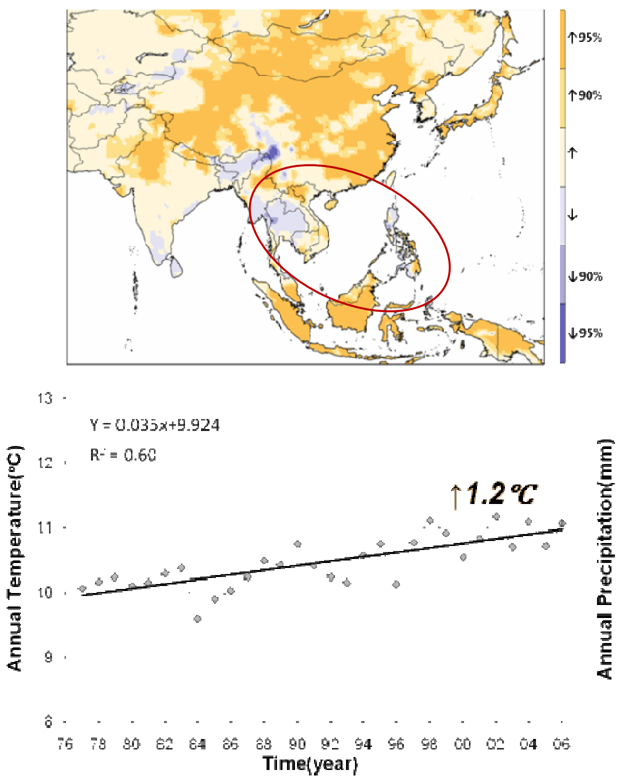
Seasonal average temperature, precipitation and runoff over the Asian regions

- **Higher T & P in summer and lower T & P in winter season due to Asia monsoon impacts**
- **The seasonal changes of T & P in Southeast Asia region are small**



Trend analysis of historical climate and hydrology

- **Annual average temperature, precipitation and runoff**
  - **Increasing trend of T and decreasing trends of P & Q over the region during last 30 years**
  - **The opposite trends of T in northern regions of Southeast Asia and of P & Q in northern regions of Southeast Asia and northeastern regions of South Asia**



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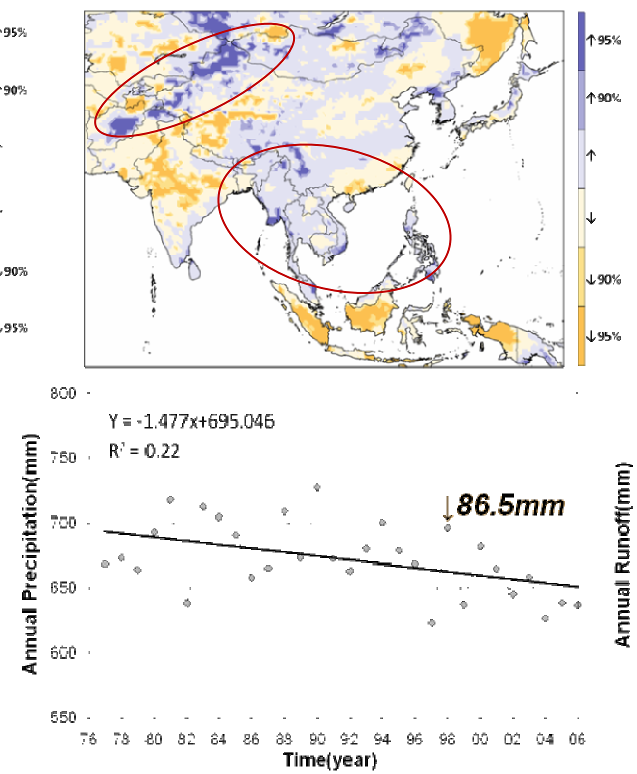

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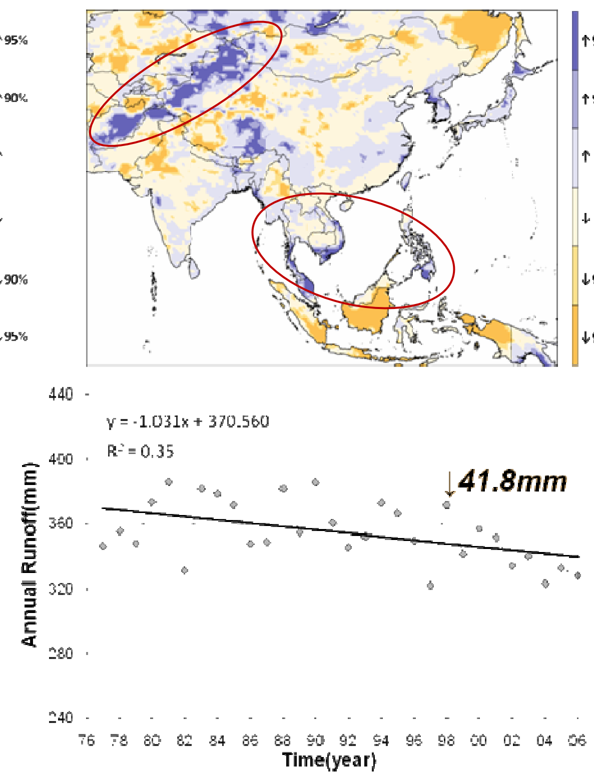
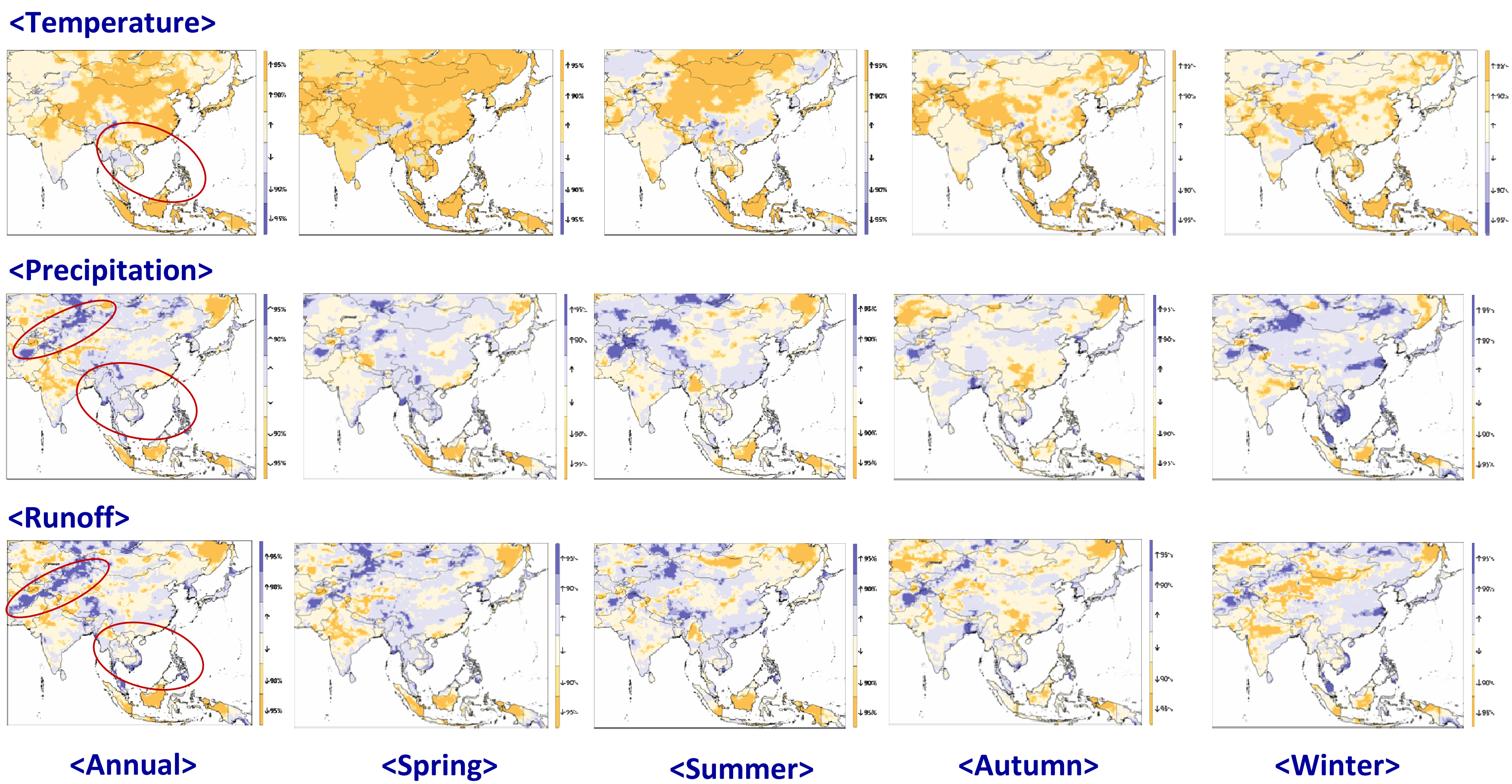


<Runoff>

- **Seasonal average temperature, precipitation and runoff**
  - **Decreasing summer T is dominant, but seasonal trends are similar to the annuals**

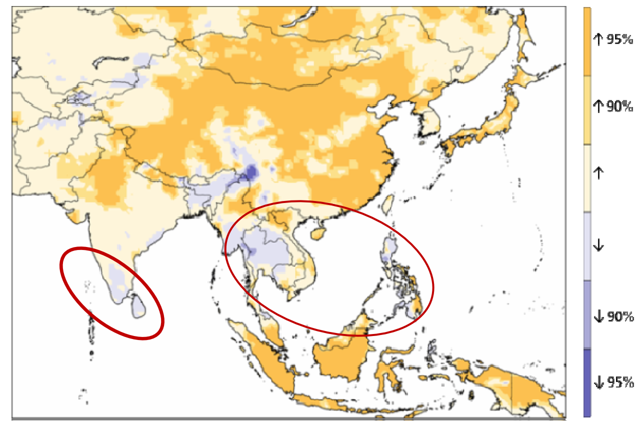


➤ Trend analysis of annual & seasonal temperature for 18 AWCI basins

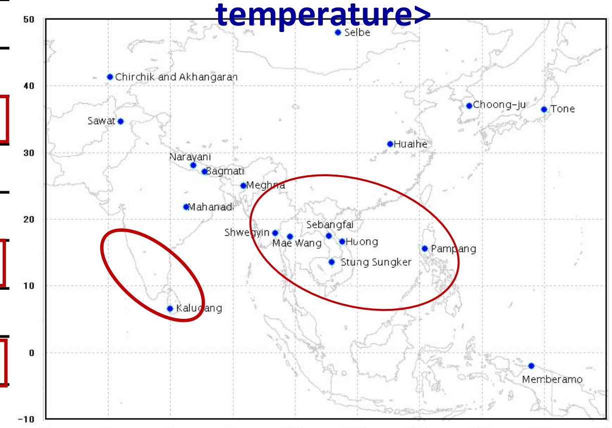
- **Similar to the characteristics of Asia domain results**
- **Decreasing trend of T in northern regions of southeast Asia and in southern regions of South Asia, but the rest of the basins have increasing trends**

Country	Basin	Trend analysis of temperature				
		Spring	Summer	Autumn	Winter	Year
Bangladesh	Meghna	▽	△	▽	▽	▽
Bhutan	Punatsangchhu	△	▽	△	△	△
Cambodia	Sangker	▽	▲	△	△	▲
India	Seonath	△	△	△	△	△
Indonesia	Mamberamo	▲	▲	▲	▲	▲
Japan	Tone	△	△	△	△	▲
Korea	Chungju-dam	△	▽	△	△	△
Lao PDR	Sebangfai	△	△	▲	△	▲
Malaysia	Langat	▲	▲	▲	▲	▲
Mongolia	Selbe	▲	▲	△	△	▲
Myanmar	Shwegylin	▽	△	△	△	▽
Nepal	Bagmati	▲	▲	▲	▲	▲
Pakistan	Gilgit	△	△	▲	▲	▲
Philippines	Pampanga	▽	▽	△	△	▽
Sri Lanka	Kalu Ganga	▽	△	△	△	△
Thailand	Mae Wang	▽	▽	▽	△	▽
Uzbekistan	Chirchik-Okhangaran	△	△	▲	▲	▲
Vietnam	Huong	△	△	△	△	▲

▲ increasing trend, ▼ decreasing trend at 95% confidence level



<Trend analysis of annual temperature>



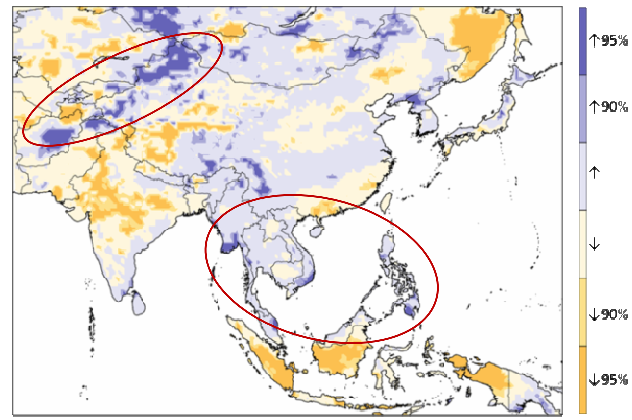
<18 AWCI demonstration basins>

➢ Trend analysis of annual & seasonal precipitation for 18 AWCI basins

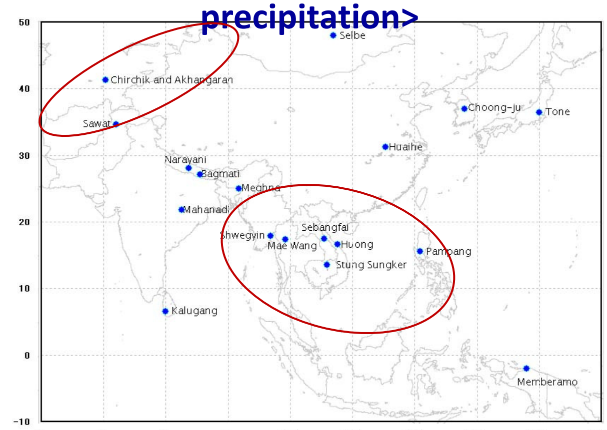
- Similar to the characteristics of Asia domain results
- Increasing trend of P in northern regions of southeast Asia and in northeastern regions of South Asia, but the rest of the basins have decreasing trends

Country	Basin	Trend analysis of precipitation				
		Spring	Summer	Autumn	Winter	Year
Bangladesh	Meghna	▽	△	△	▽	△
Bhutan	Punatsangchhu	△	▽	▽	△	△
Cambodia	Sangker	▽	▽	▽	△	▽
India	Seonath	▽	△	△	△	▽
Indonesia	Mamberamo	▼	▼	▼	▼	▼
Japan	Tone	△	▽	△	△	△
Korea	Chungju-dam	△	△	△	△	△
Lao PDR	Sebangfai	△	▲	▼	▽	▽
Malaysia	Langat	▽	△	△	▲	▲
Mongolia	Selbe	▽	▽	▽	△	▽
Myanmar	Shwegylin	▲	▽	▽	△	△
Nepal	Bagmati	△	▲	▽	△	△
Pakistan	Gilgit	▲	▲	▲	▲	▲
Philippines	Pampanga	△	△	▽	▲	△
Sri Lanka	Kalu Ganga	△	△	△	△	△
Thailand	Mae Wang	△	△	△	△	△
Uzbekistan	Chirchik-Okhangaran	▽	△	△	△	△
Vietnam	Huong	△	△	▽	▲	▲

▲ increasing trend, ▼ decreasing trend at 95% confidence level



<Trend analysis of annual precipitation>



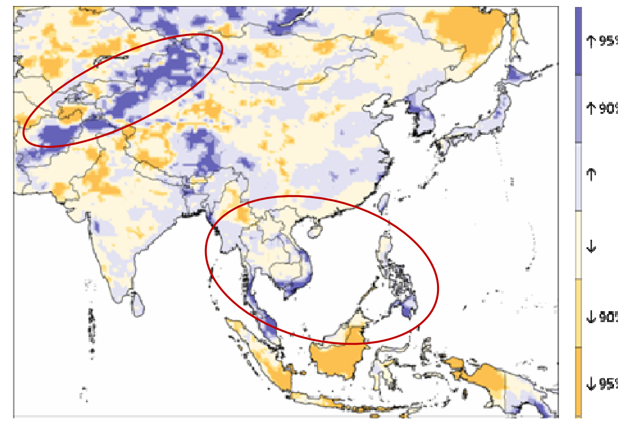
<18 AWCI demonstration basins>

➢ Trend analysis of annual & seasonal runoff for 18 AWCI basins

- Similar to the characteristics of Asia domain results
- Increasing trend of Q in northern regions of Southeast Asia and in northeastern regions of South Asia, but the rest of the basins have decreasing trends

Country	Basin	Trend analysis of runoff				
		Spring	Summer	Autumn	Winter	Year
Bangladesh	Meghna	▽	△	△	△	△
Bhutan	Punatsangchhu	△	▽	▽	△	▽
Cambodia	Sangker	▽	▽	▽	▽	▽
India	Seonath	▼	▽	△	▼	▽
Indonesia	Mamberamo	▼	▼	▼	▼	▼
Japan	Tone	△	▽	△	△	△
Korea	Chungju-dam	△	△	△	△	▲
Lao PDR	Sebangfai	△	△	▼	△	▽
Malaysia	Langat	△	▲	△	▲	▲
Mongolia	Selbe	▼	▽	▽	△	▽
Myanmar	Shwegylin	▲	▽	▽	△	△
Nepal	Bagmati	△	▲	▽	△	△
Pakistan	Gilgit	▲	▲	▲	▲	▲
Philippines	Pampanga	△	△	▽	△	△
Sri Lanka	Kalu Ganga	△	△	△	△	△
Thailand	Mae Wang	△	△	△	▽	△
Uzbekistan	Chirchik-Okhangaran	△	△	△	△	△
Vietnam	Huong	△	△	△	▲	▲

▲ increasing trend, ▼ decreasing trend at 95% confidence level



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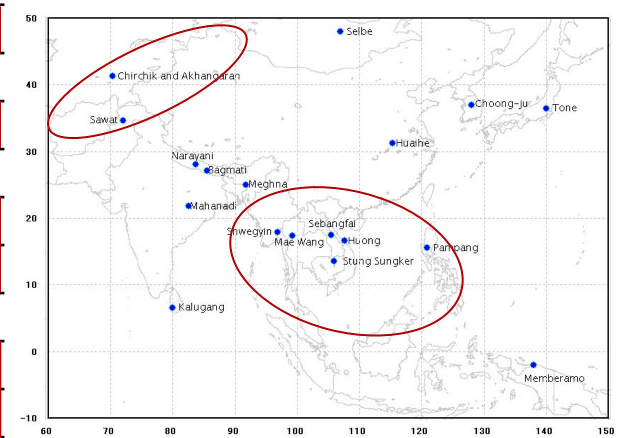
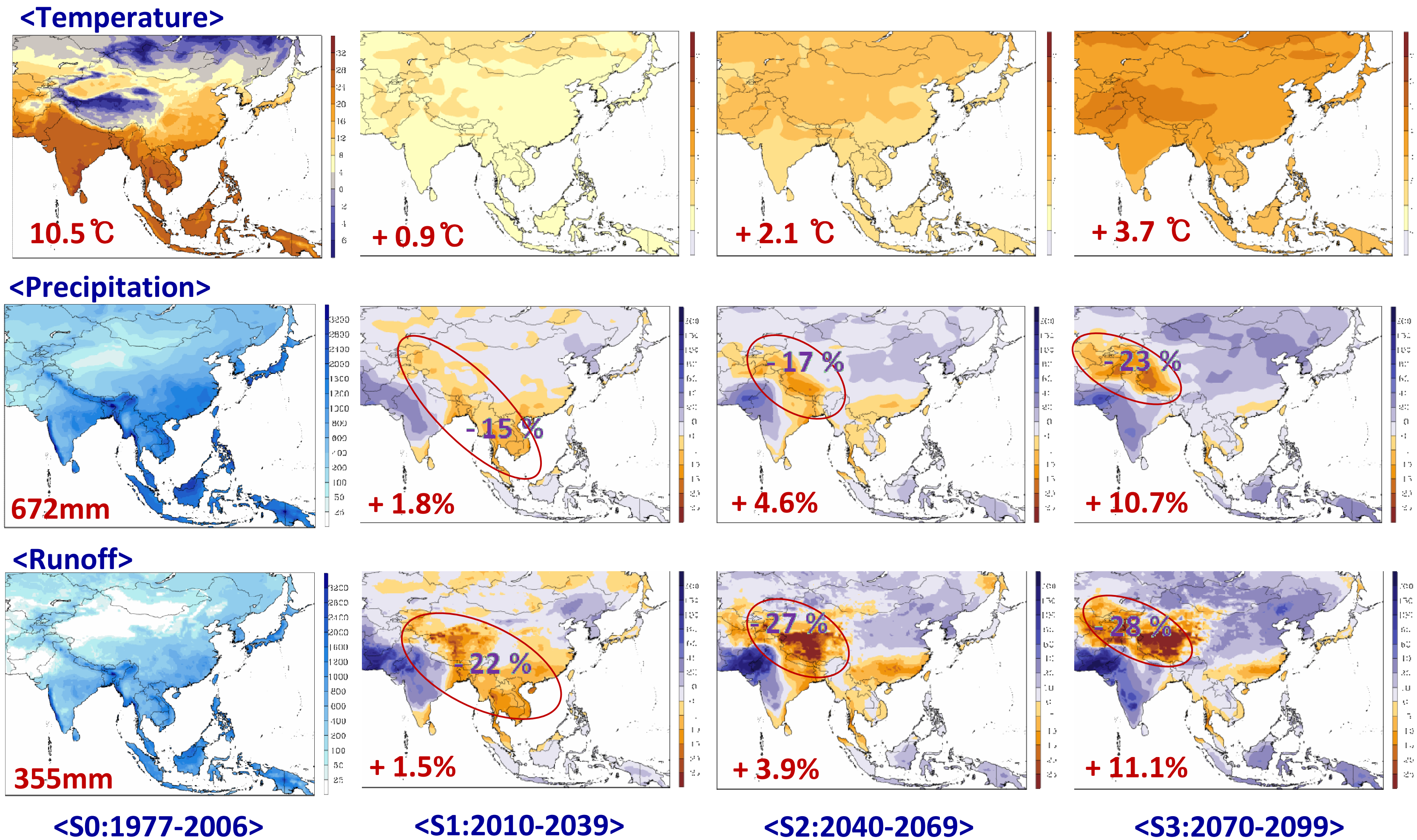


<18 AWCI demonstration basins>

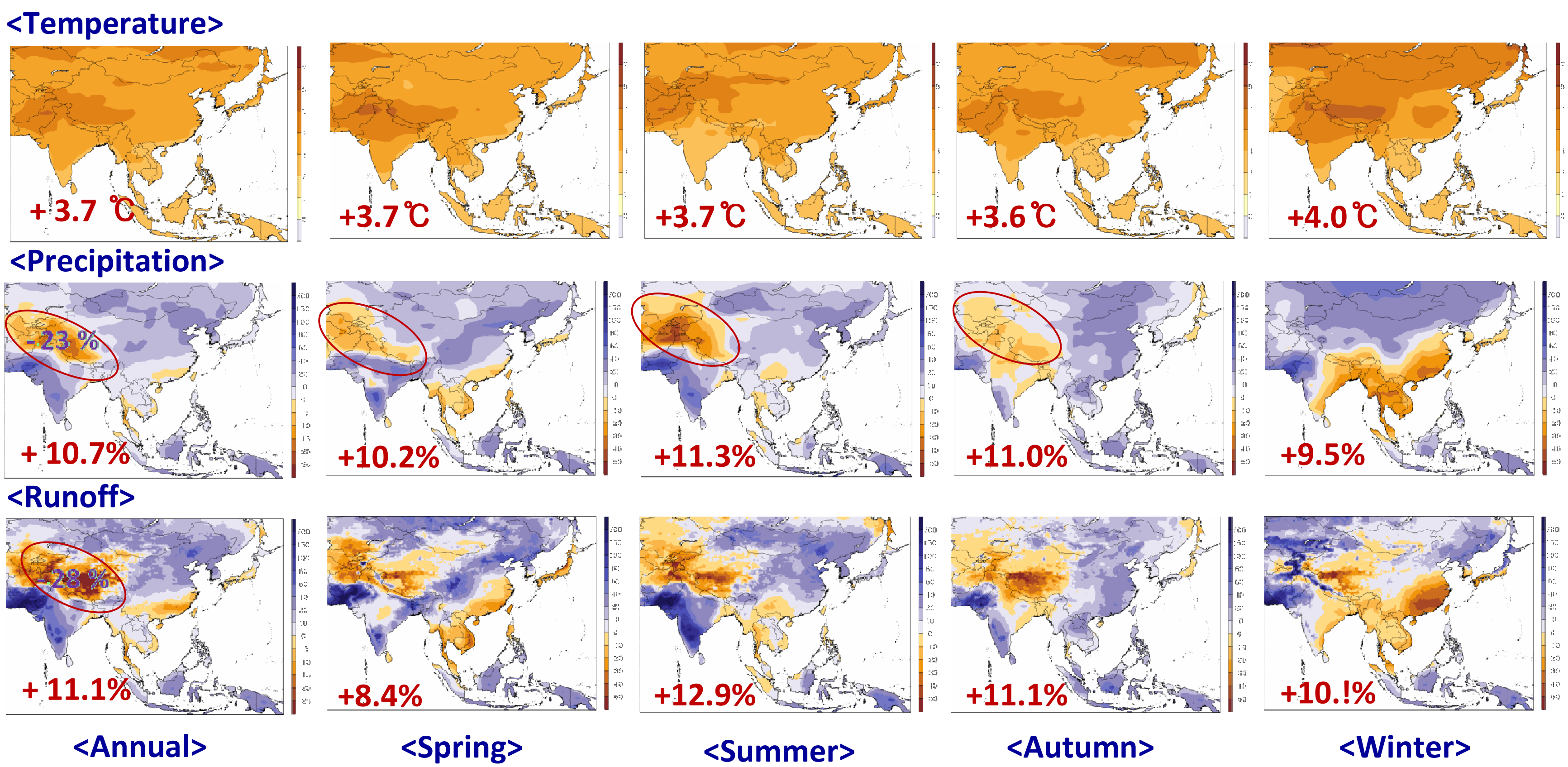
Changes in temperature, precipitation and runoff

- Increasing T over the all regions for future 3 periods and the higher increase of T in high latitude
- Increasing areal average P & Q over the regions, but decreasing P & Q in northern regions of Southeast Asia and northeastern regions of South Asia



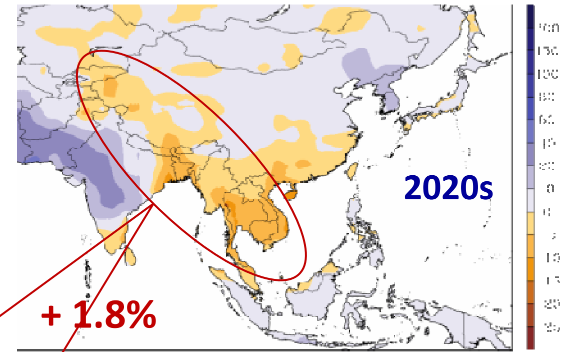
Seasonal average temperature, precipitation and runoff (S3: 2070-2099)

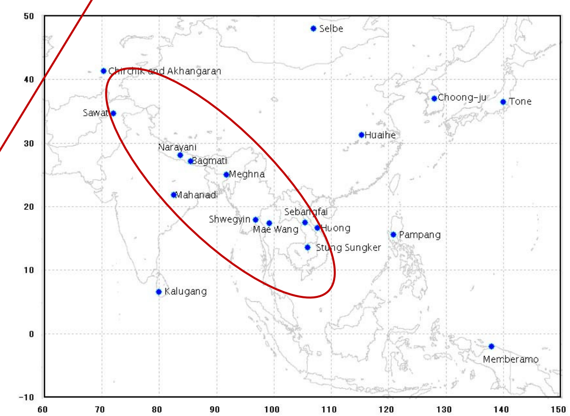
- **Increasing T for all seasons, increasing rate of T is higher in Central Asia**
- **Decreasing P in northern part of South Asia and Central Asia due to decreasing P in spring, summer and fall seasons**
- **Change rate of Q is higher than that of P, the Spatial coverage of decreasing Q is wider than that of P**



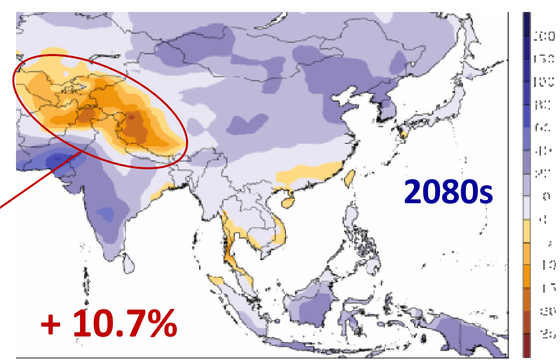
Change rate of annual precipitation for 18 AWCI basins

Div.	Country	Basin	Year 2020s	Year 2080s
East Asia	Japan	Tone	1.0	4.1
	Korea	Chungju-dam	11.6	17.7
	Mongolia	Selbe	1.9	17.6
East South Asia	Myanmar	Shwegylin	-5.4	1.6
	Lao PDR	Sebangfai	-8.2	7.2
	Thailand	Mae Wang	-7.6	3.6
	Cambodia	Sangker	-8.7	0.4
	Malaysia	Langat	-0.9	5.7
	Vietnam	Huong	-8.3	-1.3
	Philippines	Pampanga	0.6	6.2
	Indonesia	Mamberamo	6.8	21.1
South Asia	Bangladesh	Meghna	-6.4	6.6
	Bhutan	Punatsangchhu	-7.1	4.8
	India	Seonath	11.8	14.9
	Nepal	Bagmati	-1.9	7.9
	Sri Lanka	Kalu Ganga	0.1	9.3
	Pakistan	Gilgit	-3.0	-16.4
Central Asia	Uzbekistan	Chirchik -Okhangaran	2.7	-1.5



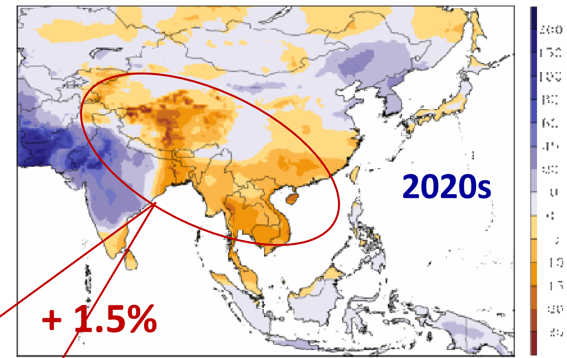


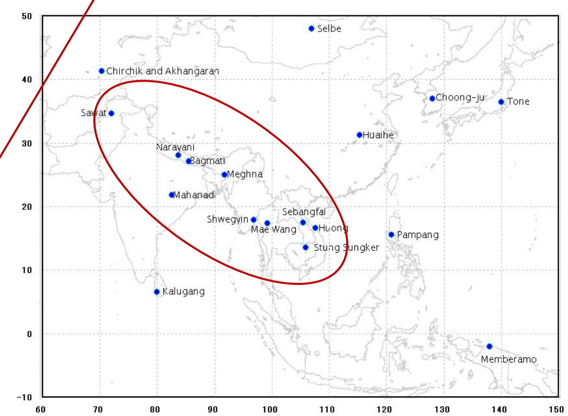
<18 AWCI demonstration basins>



➢ Change rate of annual runoff for 18 AWCI basins

Div.	Country	Basin	Year 2020s	Year 2080s
East Asia	Japan	Tone	0.5	1.2
	Korea	Chungju-dam	15.4	21.2
	Mongolia	Selbe	-0.1	16.7
East South Asia	Myanmar	Shwegylin	-7.1	0.4
	Lao PDR	Sebangfai	-11.3	8.8
	Thailand	Mae Wang	-11.7	4.3
	Cambodia	Sangker	-12.8	-0.6
	Malaysia	Langat	-1.2	6.2
	Vietnam	Huong	-10.9	-2.7
	Philippines	Pampanga	0.6	6.5
	Indonesia	Mamberamo	9.2	28.0
South Asia	Bangladesh	Meghna	-9.7	6.1
	Bhutan	Punatsangchhu	-11.0	3.8
	India	Seonath	18.8	19.5
	Nepal	Bagmati	-0.8	10.8
	Sri Lanka	Kalu Ganga	0.0	10.3
	Pakistan	Gilgit	-3.5	-19.9
Central Asia	Uzbekistan	Chirchik -Okhangaran	3.1	-3.9





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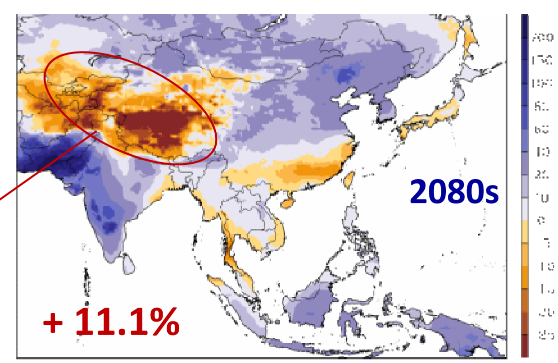
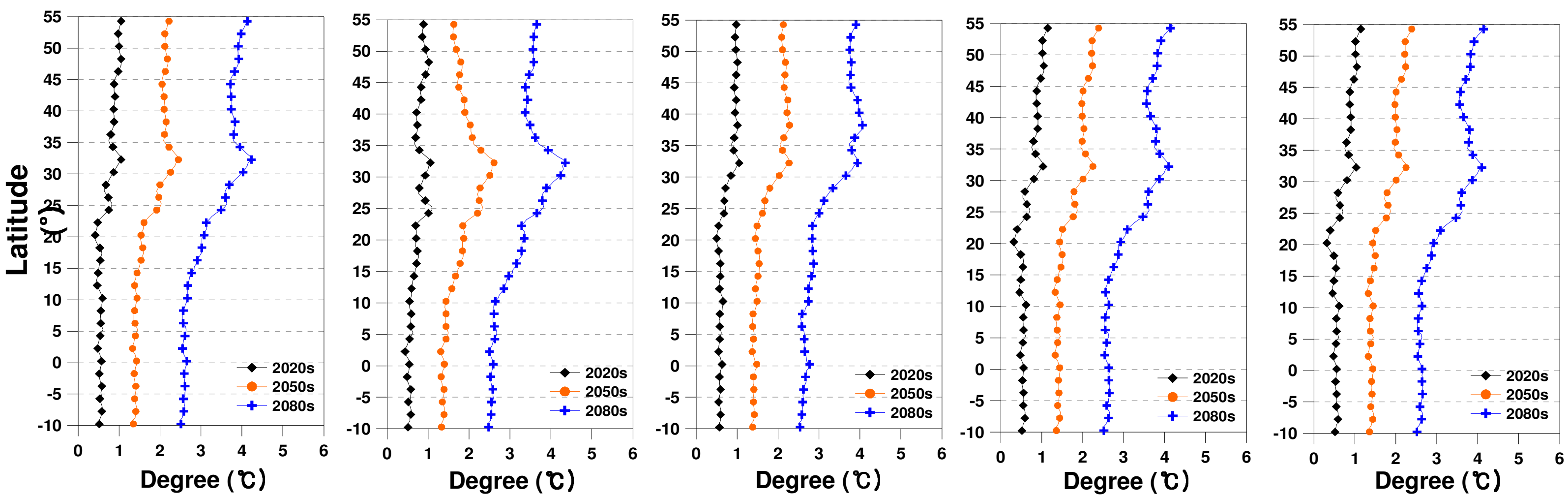


➢ Latitudinal change rate of temperature for each season

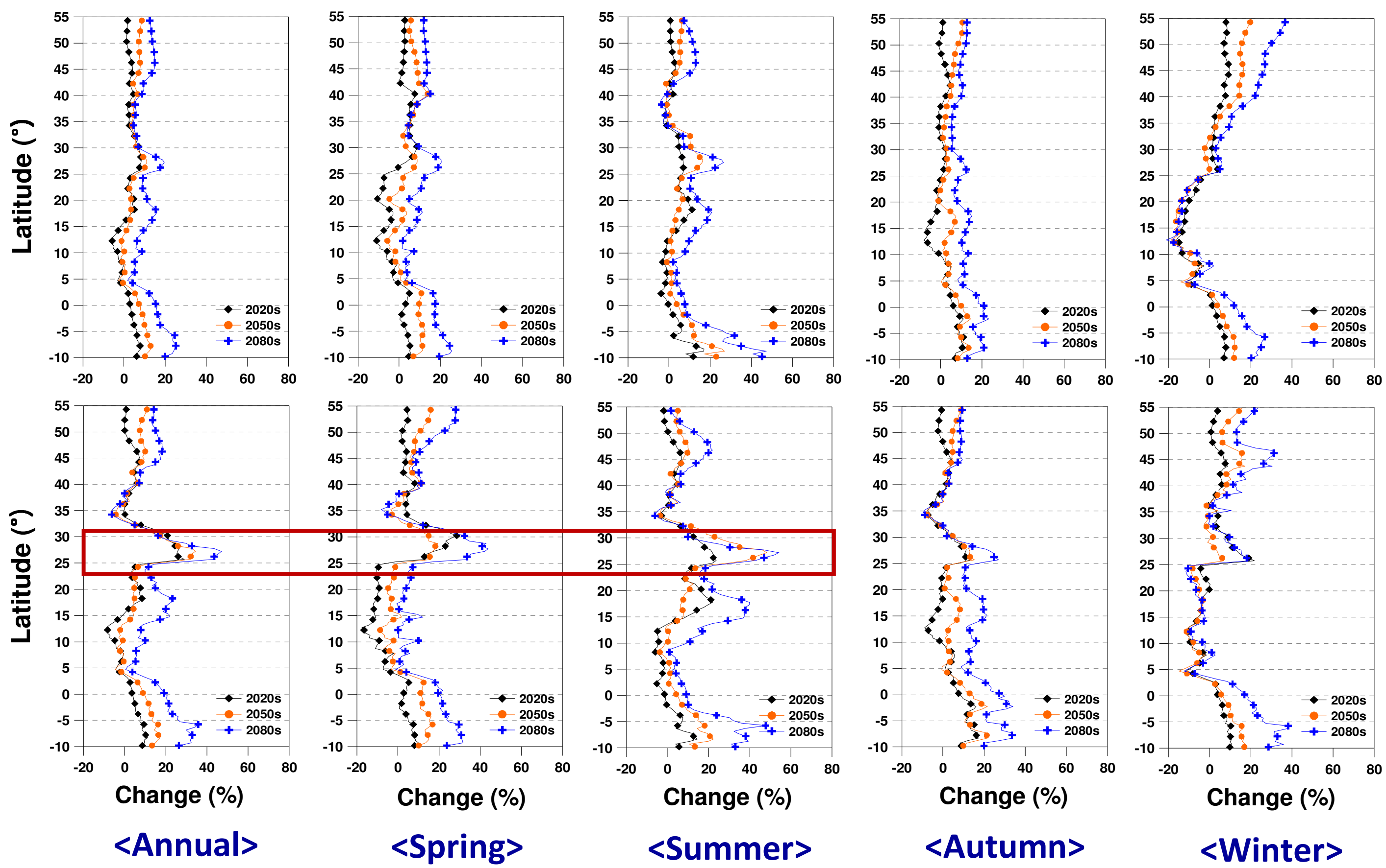
- Increasing rate of T over the regions except for 30°~35°N in spring is higher at high latitudes
- Increasing rate of T in winter is twice at high latitude (+4.9℃ , 55°N) than the low latitude (+2.4℃ , 10°S)



<Annual> <Spring> <Summer> <Autumn> <Winter>

➢ Latitudinal change rates of precipitation & runoff for each season

- **Change rates of P and Q are higher as time span goes (S1 to S3)**
- **Change rate of winter P in high latitude is higher than the P of other seasons**
- **Change rate (+42%) of Q at mid latitude (25-30°N) regions is highest than the others**



Conclusions and Future Works

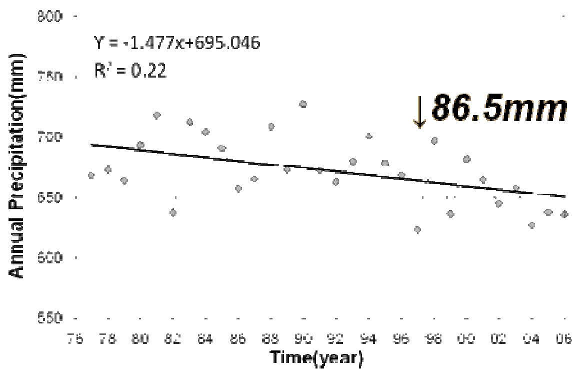
Conclusions

- **Provide the past historical climatic and hydrologic conditions during 30 years**
  - **Annual average temperature (10.5℃)**, precipitation (672mm), runoff (354mm)
  - **Runoff Ratio : 52.7%**

- **Provide the results of trend analysis for the historical data**
  - **Increasing T and decreasing P & Q over the Asia regions**
  - **Opposite trends of T in northern regions of Southeast Asia and of P & Q in northern regions of Southeast Asia and northeastern regions of South Asia**

- **Provide the results of future projections under A2 climate change scenario**
  - **Increasing areal average of T (3.7℃, 2080s) and the higher increase of T in high latitude**
  - **Increasing areal average of P (10.7%, 2080s) & Q (11.1%, 2080s) over the region, but decreasing in the northern of Southeast Asia and northeastern of Central Asia**
  - **Change rates of Q (+42%) at mid latitude (25-30°N) regions are highest than the others**

- Different trends of P and Q are detected between the results of historical data and future projection under A2 scenario
  - Uncertainty source : Emission scenario, GCMs, historical observed data, etc.



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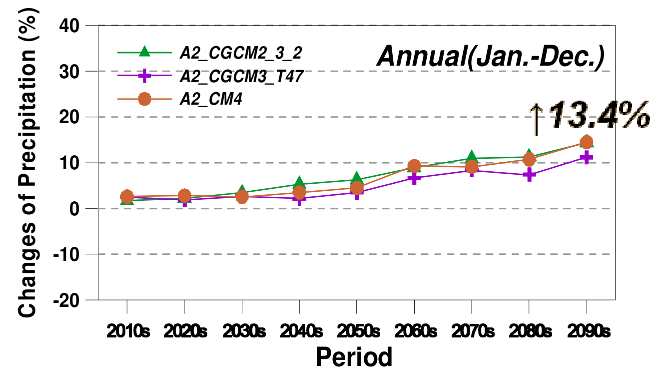
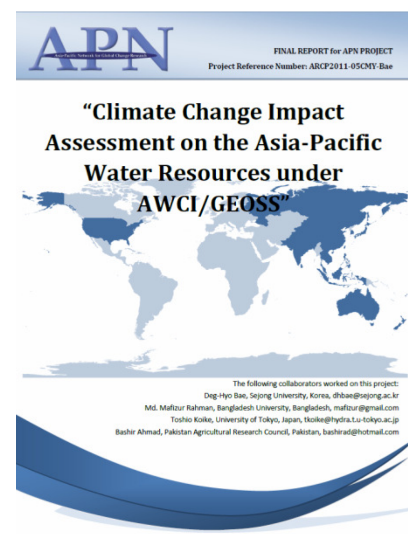


<future projection>

Future works

- For more detailed results, refer to AWCI or APN web site
- Give comments for these results after comparing your local results if available.
- Re-analyze the climate change impact assessment on water resources under RCP scenario and compare the results with those of SRES projection



Thank you